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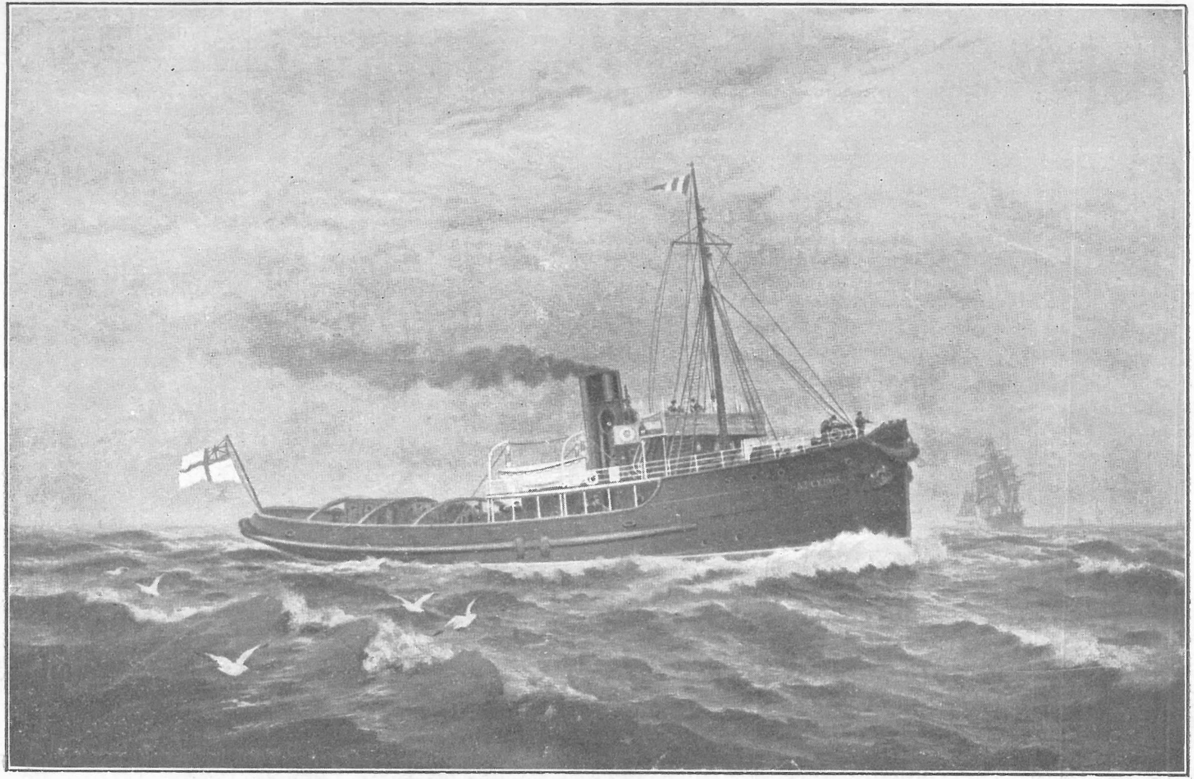

Frontispiece. OCEAN-GOING TUG. See page 10.

THE DESIGN AND CONSTRUCTION OF SMALL CRAFT.

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A.E.S.D. Technical Series.

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PREFACE.

It is not always remembered, as it should be, that the merchant marine of any country is made up of several elementary types, and that the overseas liner and the tramp are only part of the organisation of water-borne traffic. An insular country like ours, with its great coast line and well developed ports within easy reach of one another, affords possibilities in the way of short-distance sea and estuary transport which have always been taken advantage of, and it is with such vessels that the present work deals.

Much has been written on the Design and Construction of all types of large vessels, but reliable information on the smaller craft is scarce and scattered and not readily accessible. It is hoped that this volume, which deals with practically all kinds of small craft, will fill the gap in the Library of Naval Architecture.

As enormous strides have been made in the design and construction of oil engines suitable for the types of craft considered, a separate chapter has been devoted to this type of engine. The growth in the size of overseas cargo ships brings with it increased possibilities in the development of subsidiary and inter-linking services; and anyone who pauses for a moment to consider the question can see, with the introduction of the internal-combustion engine, the genesis of a revolution in the utilisation of small craft, whether on canals, estuaries or short sea routes. The demand for vessels of these types comes from all quarters of the globe and small craft propelled by internal-combustion engines are rapidly increasing in number.

The Author would like to place on record his indebtedness to the Editor of "Shipbuilding and Shipping Record," for allowing the reproduction of three articles, included in Chapters 1, 2, and 11, together with the illustrations which he originally contributed to that journal. Also to Messrs. Crichton & Co., Ltd., for the use of plans and other data. Other sources of information have been acknowledged throughout the book as far as possible.

Acknowledgment must also be made to my colleague, Mr. Leslie Knopp, F.L.M.S., for preparation of part of the work and assistance in the correction of the proof.

As the book is more or less self-contained—each chapter being complete in itself—an index has not been deemed necessary.

R. MUNRO SMITH.

August, 1924.

CONTENTS.

CHAPTER I.

SCREW TUGS.

Prior to 1840, towage as now rendered by steam tugs expressly designed for the service was practically unknown. It is of interest to note that steam towage was first employed on the Forth and Clyde canal in 1802, when a tug fitted with steam engines by W. Symington towed two barges for a distance of 20 miles in six hours against a strong headwind. The directors of the canal, however decided against this method of towage because they feared damage to the canal banks. Steam tugs are only practicable on waterways where locks are non-existent or where they are large enough to take the tug and its tow simultaneously, otherwise the advantages are more than counter-balanced by the delay at the locks.

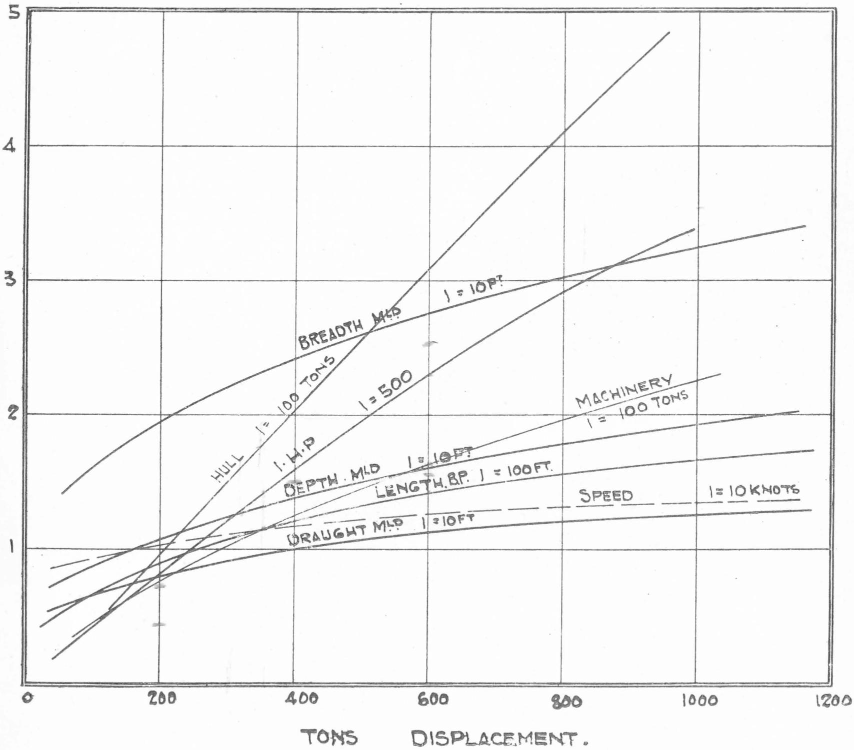

FIG. 1. CURVES FOR DETERMINING THE APPROXIMATE PARTICULARS OF TUGS.

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Tugs may be divided roughly into three classes :—

(1) Harbour tugs, up to 75 ft. in length.
(2) Sea-going tugs, from 75 ft. to 110 ft. in length.
(3) Ocean-going tugs, over 110 ft. in length.

In Fig. 1, curves are given for the determination of the approximate dimensions, etc., of tugs and the general arrangements of an ocean-going tug, a coastal tug, and a harbour tug are shown in Figs 4, 8, and 10 respectively.

The principal requirements in design of a tug are maximum stability, ample towing power, strength of construction, and good sea-going qualities. The demand for maximum stability implies the lowest possible position of the centre of gravity and minimum heeling moment. As the heeling moment depends upon the vertical position of the point of application of the towing force, the after end of the tug must be immersed as much as possible so as to ensure the lowest position of the towing arrangements. This is particularly important when the vessel is towing sideways. With a reduction in speed as a result of part of the power being used in towing, the number of revolutions decreases and the thrust per square inch of blade surface increases. Hence, good immersion is required to avoid the danger of cavitation and loss of efficiency at the propeller.

A point in the construction of tugs which appears weak to many minds is the after end of the casing which carries the towing hook and its supports. The customary strengthening of this part takes the form of brackets, tie plates or beams running to the sides of the casing. The bracket system is the most suitable from a strength point of view and is most compatible with maximum saving in the weight of steel. Another point of importance is the provision of maximum strength in the bulwarks, which are often strained in the course of the vessels work. As tugs are subjected to constant wear and tear the fitting of strong fenders is necessary and in addition, cork or rope fenders are always provided aft.

A typical towing hook is shown in Fig. 2.

In Fig. 2a, a towing hook due to Mr. Ernst Ristau, of Hamburg, is shown. The particulars have been taken from the "Shipbuilder."

The hook is so formed that the towing wire lies a little higher than the axis of a pivoting bolt round which the hook can turn. At the opposite end, the hook has a lever B provided with a tailpiece C, which lies around a second bolt D. This bolt for the portion of its length covered by the tailpiece is cut to a semicircular section, as shown in black on the illustration, Fig. 2a. The bolt D can be turned through an angle of about 60 degrees by a lever E, which is actuated by a wire led from the bridge. As soon as the bolt is turned through an angle of about 45 degrees,

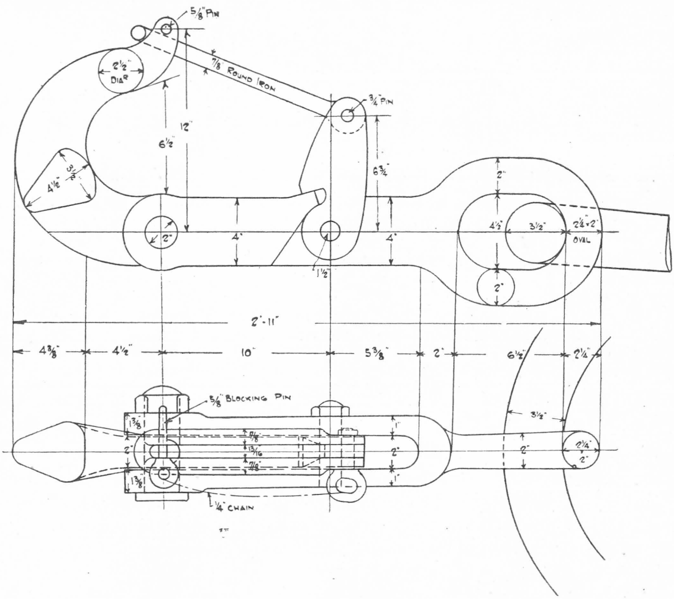

FIG 2. TOWING HOOK FOR A TUG.

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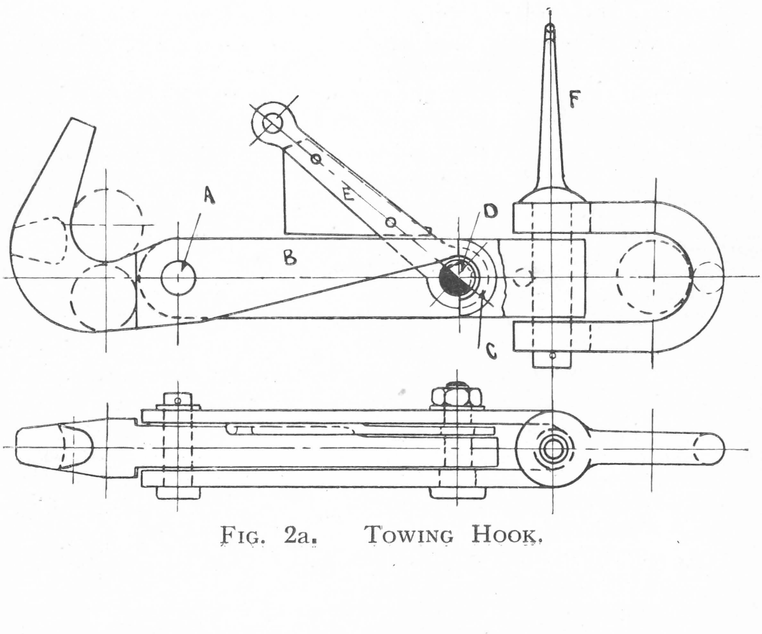

FIG. 2a. TOWING HOOK.

the grip of the tailpiece is loosened, and the hook turns around the pivot A due to the pull of the towing line, which then slips from the hook. The lever E is supported by a sheet-iron bracket in such a position that only a slight pull from the bridge will turn it. The column F, with an eye at its top, serves to lead the wire control to the bridge. This slip hook has been introduced with great success on many German tugs, leading to increased safety and the absence of accidents. The Hamburg harbour authorities have fully acknowledged its merits and require the adoption of this type of hook in all new tugs.

The conditions of service of a tug are peculiar and incompatible; running free, the speed is fairly high, and when towing, the speed may be half as much. It has usually to tow at 0.4 to 0.7 of its maximum speed and it must be capable of exerting considerable power when stationary, or nearly so, for the purpose of berthing liners. Running free, tugs differ from other classes in that, being high-powered to enable them to tow, they have relatively high speed, even though not primarily designed with that in view. It will thus be seen that the propelling machinery and especially the propellers, are a compromise, and it is to be feared that the most efficient arrangement is not always adopted, although the investigations of Prof. C. H. Peabody on the FROUDE and FULTON, given before the American Society of Naval Architects, prove useful. The main conclusions of the authors are that :—

(1) A projected area ratio of 0.5 with four blades is unnecessary.

(2) Plain oval-tipped propellers are more efficient than those with very broad tips.

(3) Moderate variation in blade area has little effect on efficiency.

(4) When stationary the greatest pull is obtained with the smallest pitch ratio, and vice-versa.

Generally, the best shape of blade for a tug is the elliptical one, the best pitch ratio 1 to 1.1, while the projected area ratio need not exceed 0.5 Other experiments confirmed the advantage of a long tow-rope, not only for elasticity reasons but to avoid wake effects. If L represents the length of the tug, increasing the length of line from 2L, to 6.5L saves 10 per cent. of the power; but the power when towing abreast is 10 or 12 per cent. more than when towing with a length 3L. The most efficient towing, when the water is smooth, is alongside.

It is also shown by Peabody's investigations that as tugs are likely to be driven well up to the critical speed at which the power increases more rapidly than the cube of the speed, the common method of using an Admiralty coefficient for estimating power is entirely inapplicable.

The speed for towing (about 0.6 full speed) is well under the critical speed, and the experiments show that power varies nearly as the cube of the speed, and consequently, the method of the Admiralty coefficient may properly be used. In the paper it is proposed that tugs be powered for towing at a speed-length ratio of 0.6 to 0.7 by the equation

$$\text{I.H.P.} = \frac{D^{\frac{2}{3}} \times V^3}{K \times L}$$

where D = displacement in tons.
V = speed in knots.
K = Admiralty coefficient.
L = length on waterline in feet.

The speed-length ratio is computed by the form $\frac{V}{\sqrt{L}}$ The speed-length ratio of the FROUDE, when towing at $3\frac{3}{4}$ knots, was 0.6, and the Admiralty coefficient corresponding 21. The FULTON, when towing at $3\frac{3}{4}$ knots, had a speed-length ratio of 0.7 and a corresponding Admiralty coefficient of 22.5.

It must be noted that the owner may demand :—

(1) a certain power to be developed by the engines

(2) a certain deadweight in a specified number of barges to be towed at a specified speed.

and (3) a certain pull on the rope to be exerted at a specified towing speed with engines developing full power.

Separate calculation of the resistance of barges must be made and these may be done by means of the following formulæ given by Mr. Kari in the "Draughtsman."

$$\text{E.H.P. per barge} = C\,\frac{\Delta^{\frac{2}{3}} \times B^{\frac{1}{3}} \times V^{\frac{10}{3}}}{L^{\frac{2}{3}}}$$

Where Δ = displacement in tons
B = breadth moulded in feet
L = length B.P. in feet
V = speed in knots
C = 0.0252 for normal river depth.

The indicated horse power which is required to propel the tug at 5 knots and which is seldom exceeded under actual working

conditions, may be similarly estimated from the same equation, using the value of 0.02875 for the coefficient "C."

The thrust exerted by the propeller bears a certain relation to the required-pull on the rope and may be expressed as follows :—

$$\frac{\text{Thrust in lbs.}}{1 + W} = \text{Resistance of barges in lbs at a speed of V knots.}$$

Where W is Froude's wake factor and V = towing speed. The thrust exerted by a propeller depends upon its efficiency and is a function of the real slip. The latter may be estimated from expression (A) which implies the knowledge of the number of revolutions at the reduced speed, with engines developing full power.

$$\text{Real Slip} = \frac{N \times P - 101.3VA}{N \times P} \qquad (A)$$

Where N = number of revs.
P = pitch in feet.
VA = speed of advance of the screw.

The number of revolutions decreases with a reduction in speed and varies as the speed to the first power. This relation may be expressed as follows :—

$$r = R[1 - 0.02(V - v)] \qquad (B)$$

Where V = maximum speed in knots.
R = revs. at speed V.
v = towing speed in knots.
r = revs. at speed v.

When the number of revolutions and the slip have been calculated from expression (A) and (B) the thrust of the propeller may be estimated from the following expression :—

$$\text{Thrust in lbs.} = d^2V^2A \times B \times \frac{P_1 + 21}{P_1} \times \frac{1.02S(1 - 0.08S)}{(1 - S)^2} \qquad (C)$$

Where d = diameter of propeller
VA = speed of advance of the screw.
B = blade factor from Froude's propeller experiments.
P_1 = pitch ratio.
S = slip ratio calculated for the respective speed and number of revolutions.

Some difficulty may be experienced in estimating the thrust at zero speed if required. It will be observed that for a slip ratio of 1.0 equation (C) becomes infinity, which is, by no means correct. To get the thrust under these circumstances, much experimental data is required, particularly that for mooring trials.

In 1913, Thornycrofts made a comparative trial of the pulling powers of a paddle tug and of a screw tug at different horse-powers as registered by a dynamometer. The results are embodied in "Marine Propellers," by S. W. Barnaby, M.I.C.E., and are given here by his kind permission.

The paddle tug was H.M.S. STURDY, 145 ft. on W.L., by 28 ft. by 15 ft, and 50 ft. over sponsons, with diagonal compound engines of 1,500 i.h.p. The feathering wheels were 16ft. 4in. diam. over the floats. There were eight floats, 9ft. by 3ft. 2in., and the upper edge of the lowest float was immersed 6in. The twin-screw tug was the NEPTUNE, 130ft., W.L., by 25ft. × 12ft. 6in. This vessel had engines of 1,600 total i.h.p., driving four-bladed screws of 10ft. diam., and 13 ft. pitch, with an expanded area of 37.5 sq. ft. Both tugs were lashed by long hawsers to a quay wall, and the pulls measured at various horse-powers. Fig. 3 shows the pulls recorded on the dynamometer. The STURDY registered a maximum of 866 i.h.p., or 58 per cent. of the power available, running free. The NEPTUNE developed a maximum of 1,170 h.p., or 73 per cent of the power available when running free, The result brought out by the trial was, as shown by the curves, that at all powers the pulls registered by the screws exceeded those of the paddle.

The results compare as follows :—

I.H.P.	Pull in Tons (screws)	Pull in Tons (paddles)
100	4.0	2.8
200	6.0	4.7
300	7.4	6.1
400	8.4	7.3
500	9.3	8.2
600	10.0	8.8
700	10.6	9.4
800	11.2	9.8
866	11.5	10.1

In spite, however, of all the work that has been done in connection with the design of propellers for tugs, it is most remarkable to note the extraordinary difference in practice of tug designers in different countries. This no doubt arises partly from the different ways in which they are handled.

In the following table particulars are given of cast-iron propellers for tugs :—

No.	Speed in Knots.	I.H.P.	R.P.M.	Blade Area Sq. Ft.	No. of Blades.	Pitch feet.	Diameter feet.	No. of Screws
1	9.0	195	123	20.8	3	8.0	7.0	1
2	9.2	240	143	17.4	4	8.0	6.5	1
3	10.2	340	142	17.5	3	8.5	7.0	1
4	10.25	365	118	28	3	9.75	7.75	1
5	10.25	420	112	27	4	11.5	8.5	1
6	11.0	460	140	26	3	10.5	7.5	1
7	11.3	670	123	28	4	11.5	8.5	1
8	11.75	830	102	28	4	14.0	8.0	2
9	12.5	1,300	128	34	4	12.0	10.5	1
10	13.0	1,400	118	32	3	12.5	9.5	2

NOTE.—The average tow-rope pull at low speed = 1 ton per 100 i.h.p.

The following results of the progressive trials of a screw tug taken from "Steamship" are interesting.

The particulars of the vessel are as follows :—

Length B.P.	72′ 0″
Breadth mld.	14′ 9″
Draught for'd.	3′ 10″—mean 5′ 7¼″
,, aft.	7′ 4½″
Displacement	69 tons
Block Co-eff.	.406
Propeller pitch	7.63′
Wetted surface	1,117 sq. ft. (about).

During the trials the thrusts were measured at thrust block by a hydraulic dynamometer, while the values of E. H. P. were determined from model experiments.

PROGRESSIVE TRIALS.

Knots.	I.H.P.	T.H.P.	E.H.P.	$\dfrac{D^{\frac{2}{3}} V^3}{\text{I.H.P.}}$	$\dfrac{\text{E.H.P.}}{\text{I.H.P.}}$
6.97	31.03	19.76	15.8	184	.509
8.07	50.56	33.16	27.42	174	.543
9.02	80.24	53.22	42.74	154	.533
10.07	132.35	89.43	70.69	131	.534
10.47	170.83	118.85	87.75	114	.514
10.84	230.58	161.40	108.46	93.4	.471
11.01	260.32	180.29	120.22	86.3	.462

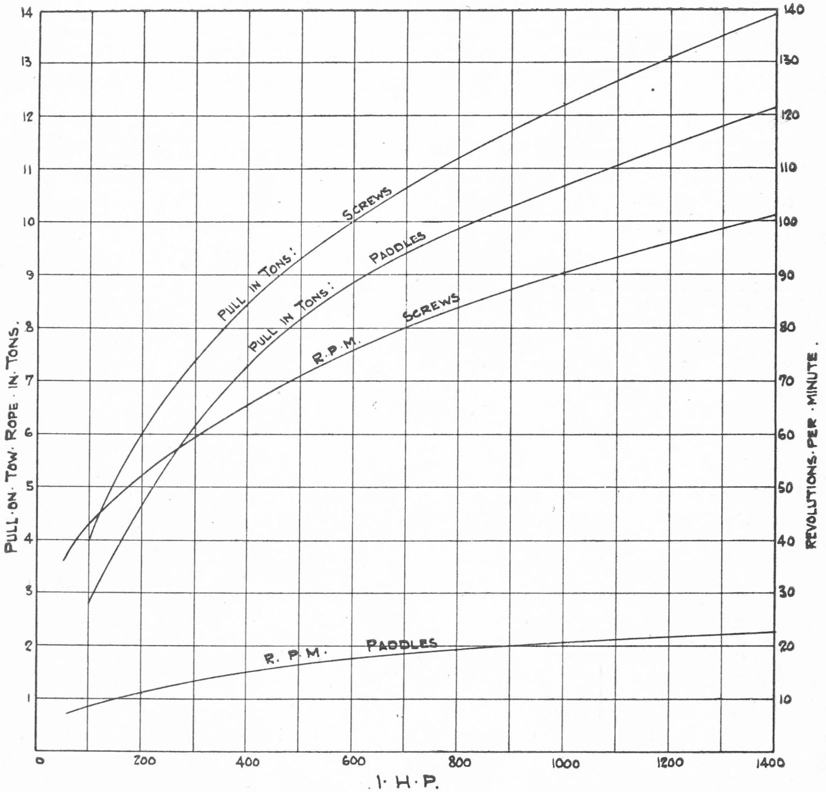

FIG 3. COMPARATIVE CURVES OF THE PULLING POWERS OF A PADDLE TUG AND A SCREW TUG.

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T.H.P.

I.H.P. varies with increases of speed from 0.64 to 0.69. Slip varies from about 1.5 per cent. to 19 per cent.

Mention has already been made of the advantage of having a long tow-line, but the length of the line naturally varies with circumstances. It is better, however, to have too much than too little, and the use of a margin of safety may result in security from accidents and delays.

In deep-sea work the heavier the line the easier the towing. A decided dip or catenary gives the same advantage in towing as does a long slope of cable with a ship riding at anchor. The sag acts as an elastic spring, preventing variations in the tension,

as by the action of heavy waves striking the bows of the tow, being thrown on the tow-line in sudden jerks. It also ensures that the forces arising in the sea-way are absorbed gradually. It is of importance, when towing in a sea-way, to arrange vessels as far as possible to ride the waves together. If the length of the line puts one vessel in the trough of the sea when the other is on the crest, the line will slacken for a moment and then tauten with a sudden jerk. If, however, the vessels meet the waves at the same time, the tension on the line will remain practically steady.

The general arrangement of an ocean-going tug is shown in Fig 4. It is one of the various types built for the Admiralty

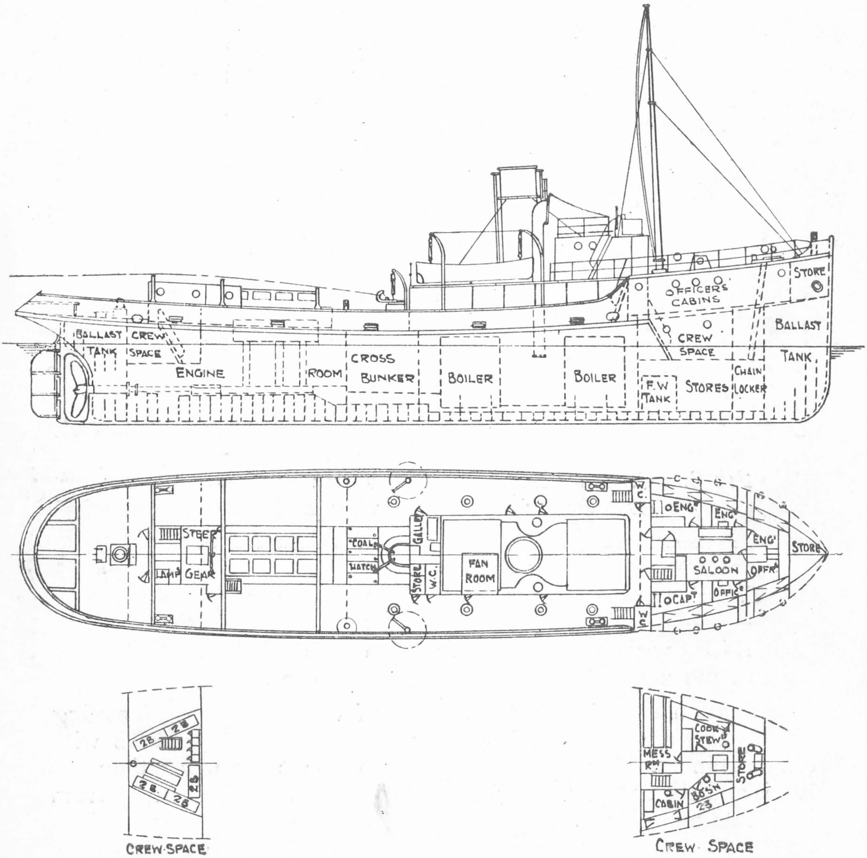

FIG. 4. GENERAL ARRANGEMENT OF THE ADMIRALTY RESCUE TYPE TUG.

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during the war and was designated the "Rescue" type. These vessels are equipped in the latest and most up-to-date manner for their intended service and with their ample sheer, combined with a bridge and forecastle, can proceed to, and operate in any part of the world.

The midship and other sections are given in Figs. 5 and 6.

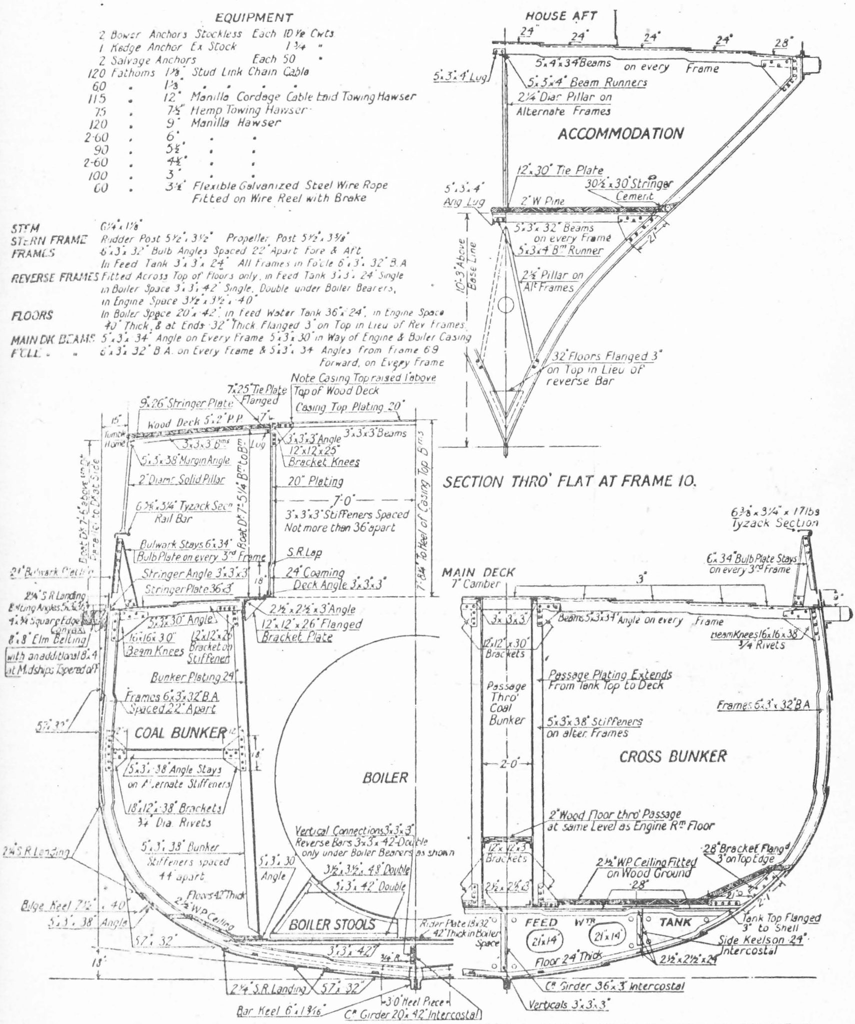

FIG. 5. MIDSHIP AND AFT SECTIONS.

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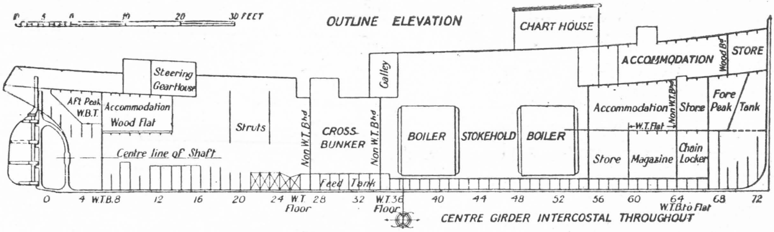

PROFILE.

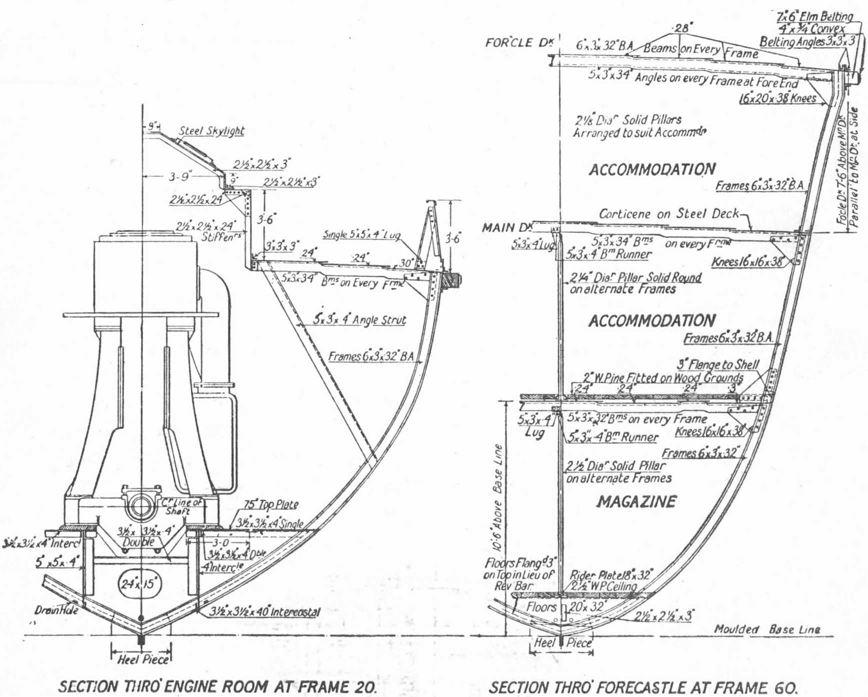

FIG. 6. CONSTRUCTION SECTIONS.

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The principal particulars are as follows :—

		ft.	in.
Length b.p.	... ...	135	0
Breadth mld.	... ...	29	0
Depth mld.	... ...	16	0
Draught ford.	... ...	12	0
Draught aft	... ...	14	6
Displacement at 14ft. 6in. aft	...	828	tons
Sheer for'd.	... ...	5	6

Sheer aft	... ...	2 6
I.H.P. on trial	... ...	1,300
Speed mean	... ...	12.5 knots
R.P.M.	... ...	128
Slip, per cent.	... ...	18

Particulars of the propeller are given in the table at No. 9.

The steel weight of this type of tug is generally $\cdot 37 \dfrac{L \times B \times D}{100}$

The crew are accommodated forward and aft under the main deck, and the captain and officers are berthed under the forecastle deck. A wheel-house and chart room are fitted at the fore-end of the bridge deck.

The cross bunkers and those abreast the boilers have a collective capacity of 245 tons at 45 cubic feet per ton. The forward and after-peak tanks have a capacity of 26 and 38 tons of water ballast respectively, and a reserve feed tank under the cross-bunker holds 19 tons. A fresh-water tank of 1,250 gallons capacity is fitted forward. All deck machinery steam operated and electric lighting fitted throughout.

The propelling machinery consists of a set of triple-expansion engines, having cylinders $18\frac{1}{4}$, $28\frac{1}{2}$ and $48\frac{1}{4}$ins. in diam., with a stroke of 28in. Steam is supplied by two marine return-tube boilers 12ft. 6in. diam., by 11ft. long and a working pressure of 180 lb. per sq. inch with forced draught. Total grate area and heating surface 87 and 3,384 sq. feet, respectively. The usual air feed and

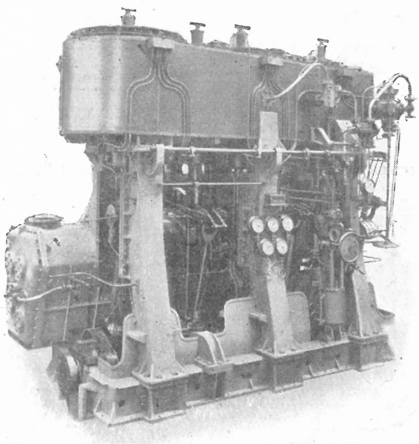

FIG. 7.

bilge pumps; duplex donkey pump; two Weir's feed pumps, distiller and evaporator; centrifugal pumps for condenser, etc., are fitted.

A photograph of the engine for this type of tug is shown in Fig. 7.

The general arrangement of a twin screw coastal and cross-channel tug is shown in Fig. 8. The principal particulars of this vessel are as follows :—

	ft.	in.
Length O.A.	91	0
Length B.P.	85	0
Breadth mld.	22	0
Depth mld.	9	6
Draught ford.	5	3
Draught aft	6	6
I.H.P.	400	
Speed (about)	10 knots	
Displacement	235 tons	

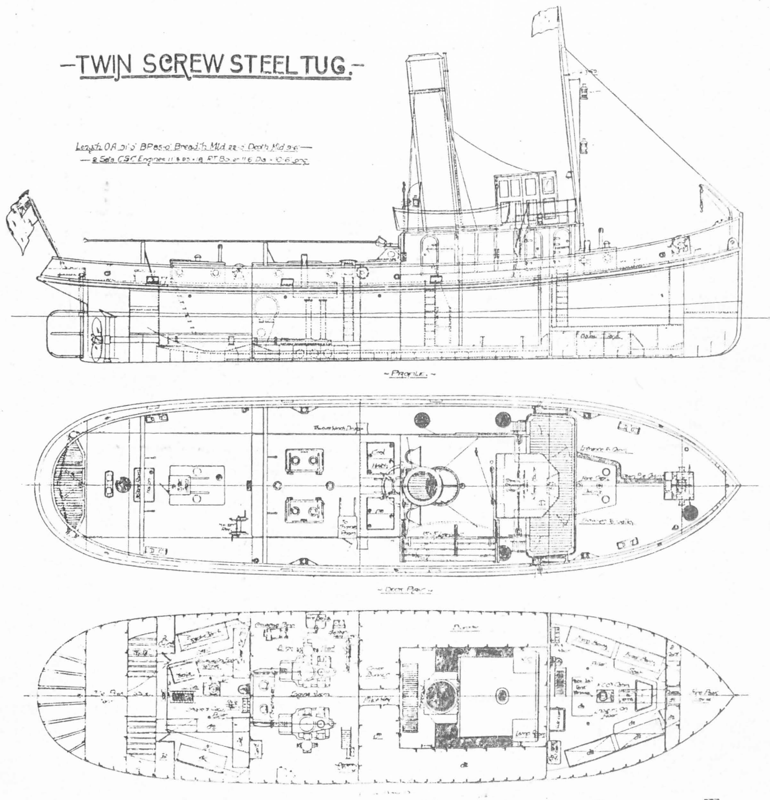

Fig. 8. General Arrangement Twin Screw Coastal Tug.

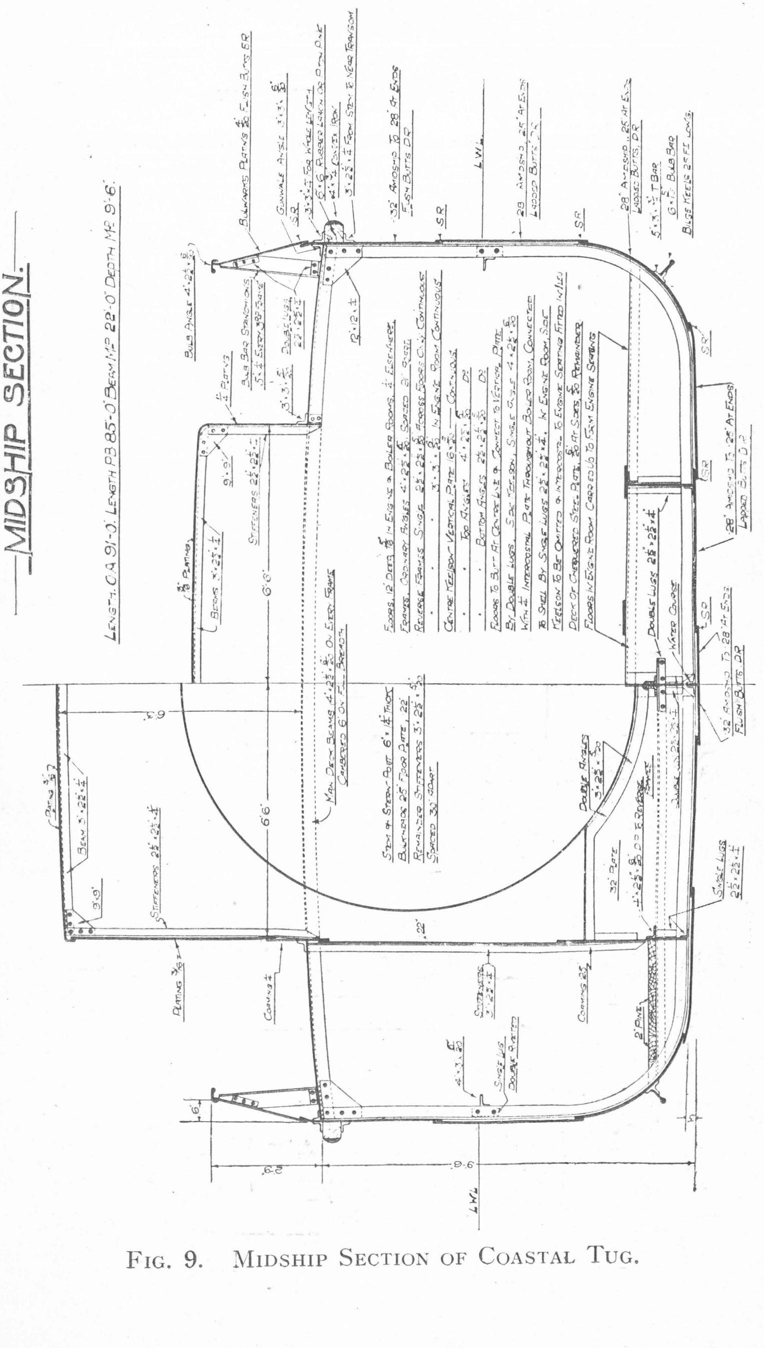

FIG. 9. MIDSHIP SECTION OF COASTAL TUG.

The displacement is made up as follows :—

Hull and equipment	105 tons
Machinery, steam up	65 ,,
Bunker Coal	55 ,,
Fresh Water, crew and effects, spare gear	10 ,,
	235 tons

The steel weight of this type of tug is generally $\cdot 40 \, \dfrac{L \times B \times D}{100}$

The propelling machinery consists of two sets of compound surface condensing engines, having cylinders 11in. and 23in. in diam., with a stroke of 16in. Steam is supplied by a boiler

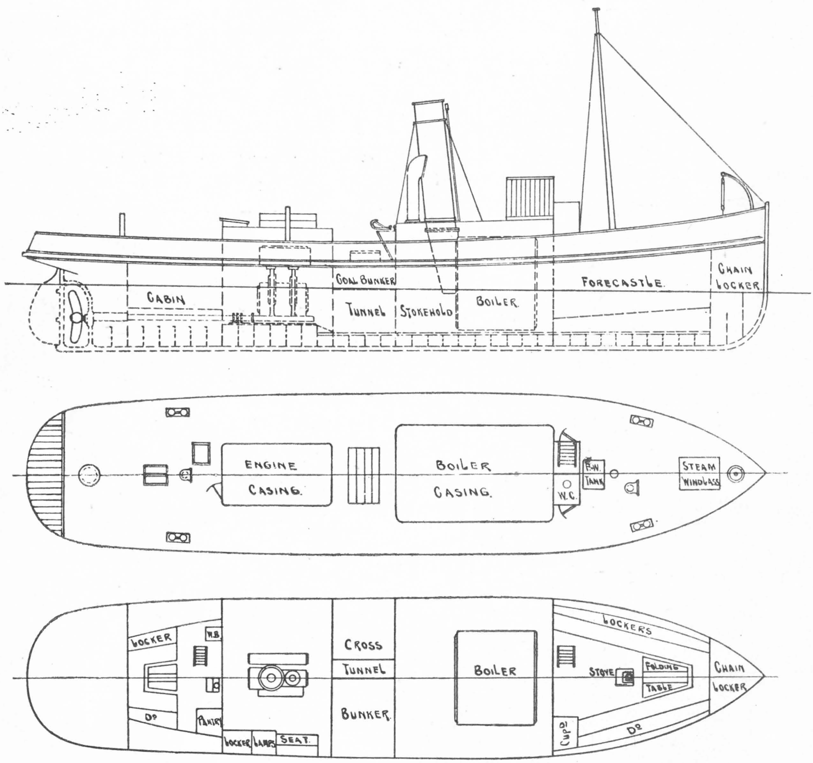

FIG. 10. GENERAL ARRANGEMENT OF HARBOUR TUG.

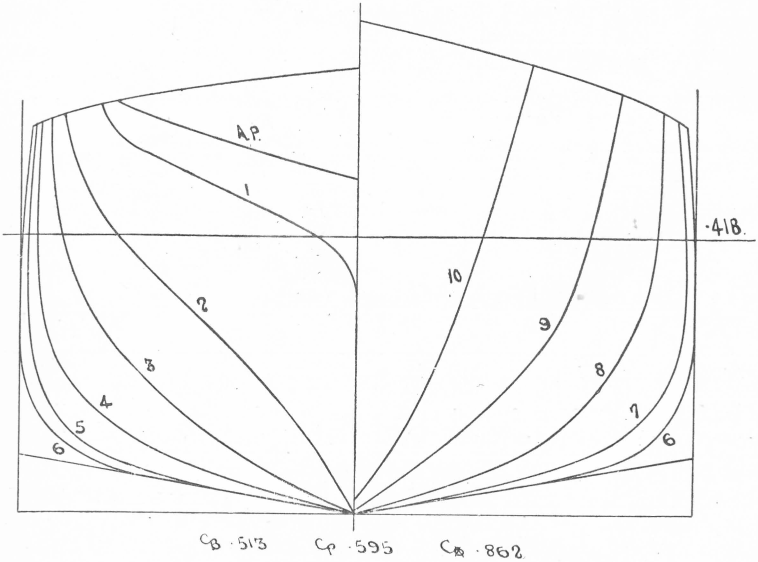

FIG. 11. BODY PLAN OF HARBOUR TUG.

of the marine return-tube type, 11ft. 6in. diameter by 10ft. 6in. long with a working pressure of 150 lbs. per square inch.

The midship section of this vessel is given in Fig. 9.

A towing winch is sometimes fitted to vessels of this class, and the advantages of these winches are principally :—

(a) That the towing hawser is wound on a drum and this drum automatically takes up the slack or gives to the strain of the tow-rope, especially when the tug and vessel towed are in a seaway. It acts on the tow-rope much in the same way as spring buffers on steering leads.

(b) When starting or ending a tow, the hawsers can be wound up on the barrel or payed out with a saving of time and labour.

The general arrangement of a typical harbour tug is shown in Fig. 10. The principal particulars of this vessel are as follows :

	ft.	in.
Length b.p.	74	0
Breadth mld.	14	6
Depth mld.	8	3
I.H.P.	260	
R.P.M.	140	
Speed	9 knots	

The crew are provided for forward and the officers are accommodated in the after-cabin.

The W.C. and entrance to the forecastle form a steel house at the fore end of the boiler casing, and on top of this the steering

gear is situated. The cross bunker has a capacity of 12 tons at 45 cubic feet. The after-peak tank has a capacity of about 5 tons.

The propelling machinery consists of a compound engine, having cylinders 13in. and 28in. diam., with a stroke of 18 in. Steam is supplied by a single ended boiler, 10ft. diam., by 9 ft. long, with a working pressure of 140 lb. per square inch. The boiler has two plain furnaces, a grate surface of 29 sq. ft., and a heating surface of 800 sq ft.

The body plan of a harbour tug is given in Fig. 11.

MOTOR TUGS.

The keen competition in tug work demands strict attention to running costs, and it is perhaps in tugs that oil engines show the greatest economy in running costs compared with steam. The oil engine not only scores in fuel cost while running, but obviates the stand-by losses of the steam tug which consumes fuel during the many unavoidable idle periods of waiting for a tow. The nature of the work is intermittent and a tug is often tied up waiting for the next job, but a full head of steam must be kept up, whereas with an oil engine, directly the vessel is off a job all fuel cost immediately ceases and it is ready for service again at five minutes notice. The reduction in crew—by the elimination of the stokers—the diminished upkeep costs and the much shorter laying up periods for overhauls, due to the absence of a boiler, are also points worthy of consideration. Another point is that the radius of action of a tug with oil engines is approximately four times that of a steam tug with the same weight of fuel, and far less time is lost bunkering oil than coal.

The Diesel engine is generally regarded as being inferior to the steam engine from the point of view of manœuvring power. If, however, the Diesel engine can be successfully fitted to a tug, a class of vessel in which it is essential that manœuvring can be quickly and efficiently carried out, it would appear that the draw-back of the Diesel engine has been successfully overcome. During the war sixteen Diesel-engined tugs were built for the French Government.

The principal dimensions are :—

Length B.P.	85′ 3″ O.A. 91′ 10″
Beam	16′ 8″
Draft	9′ 10″
Displacement	145 tons.
Fuel capacity	10.5 tons (about).

The arrangement of these vessels is shown in Fig. 12.

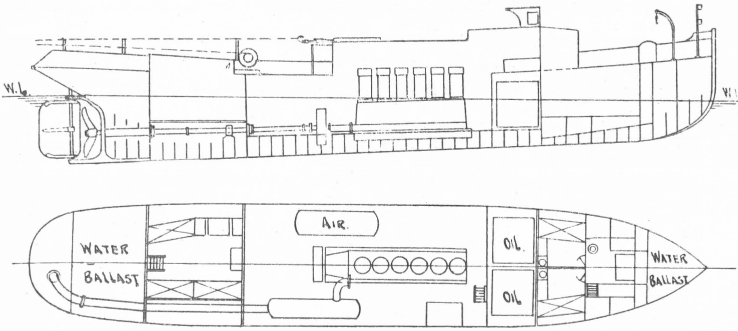

FIG. 12. ARRANGEMENT OF MOTOR TUG.

Ten of these vessels are propelled by two-cycle Diesel engines of 420 B.H.P. at about 220 R.P.M. The fuel consumption of these engines is 0.38 pound of crude oil per brake horsepower hour. The auxiliary air compressor and the electric lighting are driven by a 12 horsepower Diesel engine. The engines are of the Sulzer design. Six of the vessels are propelled by 350 horsepower Polar Diesel engines making 200 R.P.M. On account of the smaller engines in these tugs the displacement has been decreased by about five tons. In both types particular attention was paid to the design and operation of the manœuvring gear, the method of starting, stopping and reversing the engine forming the main feature of the design.

For tugs requiring smaller power, the semi-Diesel engine can also be successfully employed. The tug "Bolnes" has a length overall of 62 ft. 2 in. and is propelled by the "Bolnes" type of semi-Diesel engine. A two-cylinder unit is employed developing 130 B.H.P. when running at 240 R.P.M. The engine is fitted with clutch and reverse gear which can be operated by a handwheel in the engine room or from the bridge. For ahead running the engine is direct-coupled to the propeller shaft, and for running astern a simple train of gear wheels is introduced between the engine shaft, while the variation of speed is obtained by throttling. There is a neutral position enabling the vessel to be stopped with the engine still running, while in order to reduce fuel consumption under this condition a brake is provided so that the engine can be run dead slow, being thus instantly ready for use again. The tug can be readily manœuvred, as the engine answers quickly to any demands made upon it.

The particulars of a Diesel tugboat for harbour service are given below.

The principal dimensions are as follows :—

Length B.P.	46′ 0″
Beam	13′ 0″
Depth	6′ 3″
Draught	4′ 6″

The machinery consists of one direct reversible two-cycle Diesel engine of 100 B.H.P. at 250 R.P.M. The engine has four cylinders, each provided with an independent fuel oil pump and two air pump cylinders. The engines are reversed by compressed air from the air tanks. The auxiliary air compressor is driven by a 5 horse-power hot bulb engine, which also drives the bilge and fire pump. The cylinders are water cooled by a pump driven directly from the crank shaft.

The fuel consumption of the main engine using fuel oil of about 18,000 B.T.U.'s per pound averages 47.5 pounds per hour. There is a capacity for fuel oil sufficient for a trip of 500 miles. The time required for reversing on trial trip from full speed ahead to full speed astern was about six seconds. The average speed was nine knots.

It is of interest to note that a steam tug of the same size can only carry a few tons of coal, sufficient for about 175 miles, on account of the heavier steam installation.

The higher revolutions of the oil engine constitute a disadvantage as compared with the steam engine, but the crucial test is the towing power which can be obtained with a tug of a given size. The oil engined tug gives a bigger dynamometer pull at rest or when towing than the same sized steam tug, and that is a measure of its earning power.

From above and from actual working data of motor tugs, the following advantages for the oil engine can be taken as established :—

(1) The cost of fuel is less than one-half that for a steam installation, since the fuel consumption is between 0.4 and 0.5 lb. per B.H.P. hour.

(2) The weight of an oil engine installation is less than that of a steam installation. This permits of a reduction in dimensions for the same horse power.

(3) Stand-by losses are eliminated, since it takes only a few minutes to start up an oil engine, whereas a steam tug must have the fires burning continuously.

(4) Compared with a steam tug of the same dimensions and horse-power, the motor tug can, due to lighter machinery, carry more fuel and have a greater cruising radius,

(5) Firemen are not required on a motor tug and a saving in crew's wages is thus effected,

The general arrangement of a canal tug is given in Fig. 12A. The dimensions of this vessel are as follows :—

Length B.P.	... ...	50′ 0″
Beam extreme	... ...	7′ 0″
Draught extreme	... ...	3′ 6″

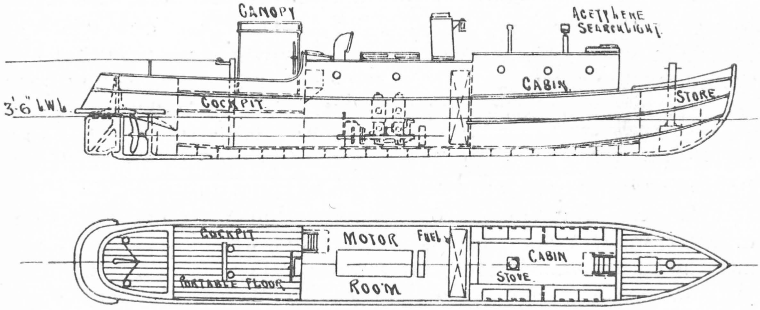

Fig. 12A. General Arrangement of Motor-Driven Canal Tug.

The hull of the vessel is constructed of iron, steel being of little or no use for canal work owing to the detrimental effect of the canal water in certain localities, this causing it to corrode with great rapidity. It will be seen that the crew are berthed forward in a cabin, the head room in same being 7 feet.

The motor is arranged amidships and is of the British Kromhout type, being a two-cylinder model capable of developing 40 B.H.P. at 425 R.P.M. As is usual in Kromhout engines of low power, a Kromhout standard reverse gear is fitted which ensures ease and rapidity in reversing, same being entirely controlled from the steering position immediately abaft the engine room. A fuel tank, having a capacity of 250 gallons, is fitted at the forward end of the motor space, whilst a daily use tank is fitted on the after-most bulkhead of the engine room. A small acetylene projector is arranged on the cabin top at the forward end of same. The bow is arranged to allow of the tug being used as an icebreaker.

Chapter 2.

STEAM TRAWLERS.

The fishing industry presents many features of interest and cannot fail to appeal strongly to the imagination of those who so

much appreciate the value of fish as an article of food, but seldom, perhaps, consider the work involved in maintaining a fresh supply to inland districts, where they perchance may reside.

The modern extension of the fishing trade has been brought about, primarily, by the evolution of steam and the resultant development of railways throughout the country. Previously the whole of the fishing industry had been carried on by sailing vessels of shallow draught and the means of transport at that time prohibited the distribution of the fisherman's goods to any great extent, and limited the supply of fresh fish to areas adjacent to the coastline. At the present day, however, these conditions are changed entirely, steam trawlers, steam herring-drifters, and other steam fishing vessels have come into being, and their size, speed, and capacity for work has in conjunction with the steam and motor transport on land revolutionised the trade. Steam was introduced in fishing vessels in 1880.

Of all steam fishing vessels, trawlers must be given first place, because they were the pioneers of steam in fishing vessels, of which they represent the largest type afloat. They exploit distant fishing grounds, and carry on the most remunerative class of trade. In his book on "Sea Fisheries," Professor Marcel Hérubel says, "To one who watches, in a large and prosperous port, such as Grimsby, Hull or Aberdeen, the arrival of the steam fishing boats, it seems that these powerful and speedy vessels must be the only efficacious agents of intensive production, as well as the regular purveyors of the market, an impression which corresponds faithfully to the reality."

The origin of the steam trawler might reasonably be described as accidental, for the first trawlers were old tug-boats plying on the rivers Tyne and Wear, whose owners, not being content with the earnings from the vessels amongst general shipping, decided to convert them for the time being into fishing craft. These vessels proved so successful that they were soon followed by specially designed vessels, in connection with which a large number of steam-fishing companies sprang into existence. There are to-day fully 2,000 steam trawlers in the United Kingdom.

These first vessels were generally about 80 ft. or 90 ft. long and of small displacement, but since that date the design of trawlers has more or less become standardised, and although the vessels at the present time vary in size to meet the requirements of the case, they are all similar as regards the general arrangement of the hull fittings and trawling gear. The increase in the size is chiefly due to the greater distance the trawlers now travel to reach remote fishing grounds, and to the larger cargoes of fish they bring to port. Many of the larger vessels have a bunker capacity of 250 tons with a fish carrying capacity of from 50 to 60 tons. Before dealing with trawlers as ships it is necessary to make reference to their primary function, trawling.

The operation of trawling is carried out by means of a large conical net, which is slowly dragged through the water by steel wire ropes, the latter being attached at one end to Otter Boards at the extremities of the mouth of the net, and at the other to one of the after quarters of the vessel. The drag ropes are generally $2\frac{3}{4}''$ in circumference and have each a length of up to 1,200 fathoms. The net now employed is known as the "otter" trawl, and was first used in 1894. Up to that time the "beam"

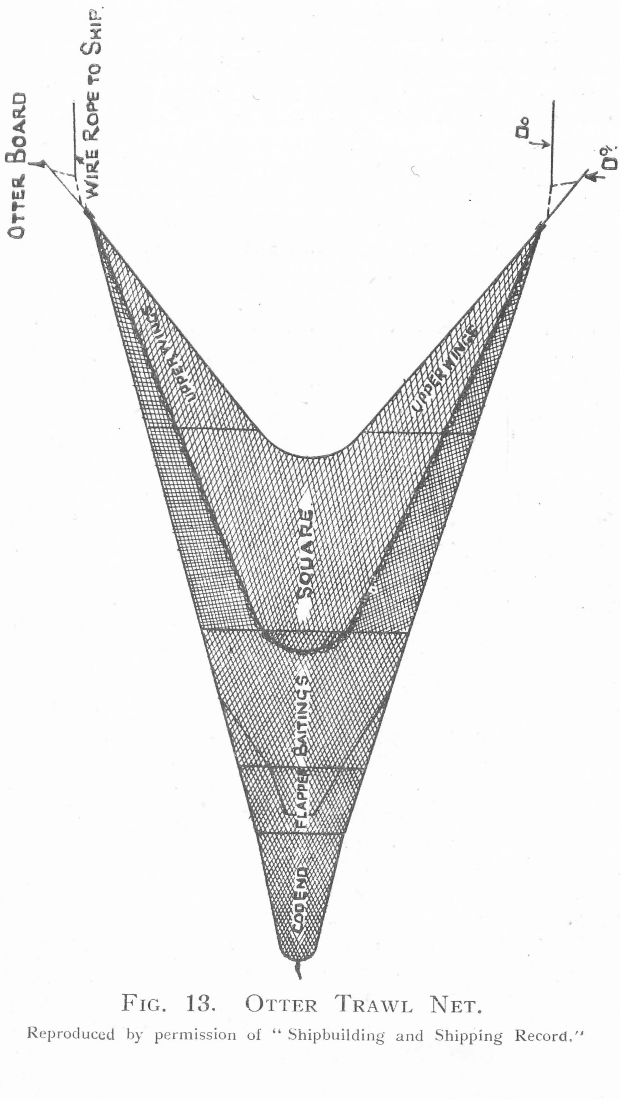

FIG. 13. OTTER TRAWL NET.

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trawl was used, but was a constant source of trouble by reason of its cumbrous weight, and by the frequent necessity of repairing it when broken on the rough bed of the sea. The form and principal features of the trawl net are shewn in Fig. 13. The lower part of the net is cut back in the form of a deep U, in order that when the fish are disturbed they will be enclosed at the sides. With the object of preventing the escape of fish underneath the net, the lower part is edged with a heavy ground rope about 8″ in circumference. Towards the narrow end of the net is arranged the flapper or trap, which encloses the pocket in which the fish are finally caught. When fishing on rough ground the foot rope is furnished with large, heavy wooden rollers, the "bobbins," as shown in Fig. 14. A.B. is balch line on head of belly and connecting with bosom of wings. S.S. are wire seizings connecting balch to small intermediate bobbins 6″ diameter (E.E.). F.F. are large bobbins up to 24″ diameter. The size of the net depends upon the size and power of the trawler towing it; some large nets are about 100 ft. long by 80 ft. wide at the opening. They are usually made of manilla twine, the mesh being about $1\frac{1}{2}''$ from knot to knot in the pocket and 3″ elsewhere. The otter trawl net has greatly increased the catch of round fish such as cod and haddock, which swim some little distance from the actual sea bottom.

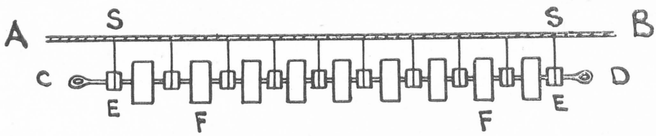

FIG. 14. FOOT ROPE "BOBBINS."

The otter boards are made of stout timber, heavily shod with iron on the edges, and are about 9 ft. long by 5 ft. deep, the weight of each being about 8 cwt. The otter board is shown in Fig. 15. The attachment of the drag ropes is so arranged that the otter boards incline outwards, when pulled through the water, at an angle of about 20 degrees, and so open the mouth of the net to a wide extent.

The appliances on board the ship for trawling consist of the trawl winch for winding in and out the drag ropes, the gallows from which the otter boards are suspended when lowering or raising the net, the deck fairleads for the drag ropes, and the towing bollards to which the drag ropes are made fast when a sufficient length has been run out. The disposition of all these appliances and the leads of the drag ropes are shown in Fig. 16. Fittings are provided on both sides of the vessel, in order that trawling may be carried out from either quarter.

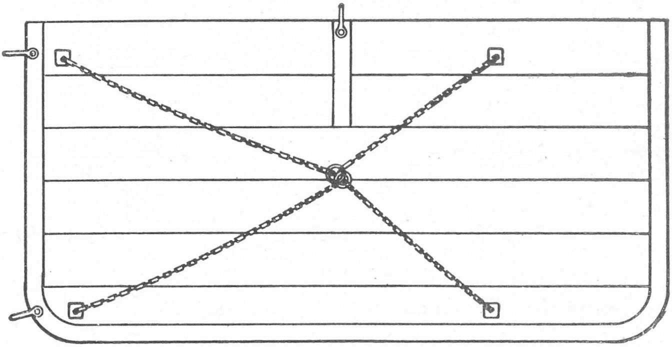

Fig. 15. Otter Board.

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The trawl winch is a powerful machine of special type to meet the requirements of trawling operations. It has two large barrels, one for each drag rope, and warping drums on each side for the final hoisting of the net on board and for pulling the drag ropes sideways to permit their attachment to the towing bollards. On the forward side of the winch are vertical roller guides, which travel laterally and so ensure the wire rolling on the drum without over-riding. Each of the barrels is fitted with a powerful brake to lock the wire when the required position is reached. When a hand windlass is fitted a gipsy wheel is put on the winch and power transmitted to the windlass for lifting the anchor by means of a messenger chain. The barrels of the winch are each capable of taking up to 1,200 fathoms of $2\frac{3}{4}''$ trawl warp and they can be operated together or separately by the action of dog clutches. About 80 I.H.P. can be developed by a modern trawl winch at 100 R.P.M. The winch is generally arranged on the raised quarter-deck just forward of the wheelhouse, the deck being raised some $12''$ so that all fish, gear, etc., can be kept from washing aft and the winch can be kept clean. The gallows are of bow shape inclined towards the side of the ship, and are generally

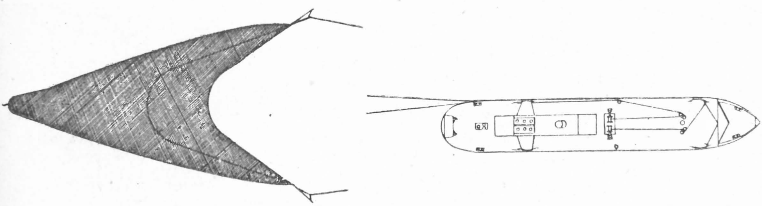

Fig. 16. Diagrammatic Arrangement Showing the Disposition of the Deck Fittings and the Leads of the Trawl Net Ropes.

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formed by a strong H bar which is securely attached to the deck by means of plate knees and supported by stays riveted to the top of the gallows and bolted to the deck. The after gallows with its block is shown in Fig. 17. The centre and side fairleads for the drag ropes are shown by Figs. 18 and 19 respectively, and also in Fig. 16.

In the early days of steam trawling, manilla ropes were used, but these were very soon displaced by galvanised patent flexible steel wire ropes capable of withstanding the very heavy strains and severe compression which accompany trawling operations. Only those who have stood by the winch during trawling operations under normal fine weather conditions can realise the plucking, grinding and straining—

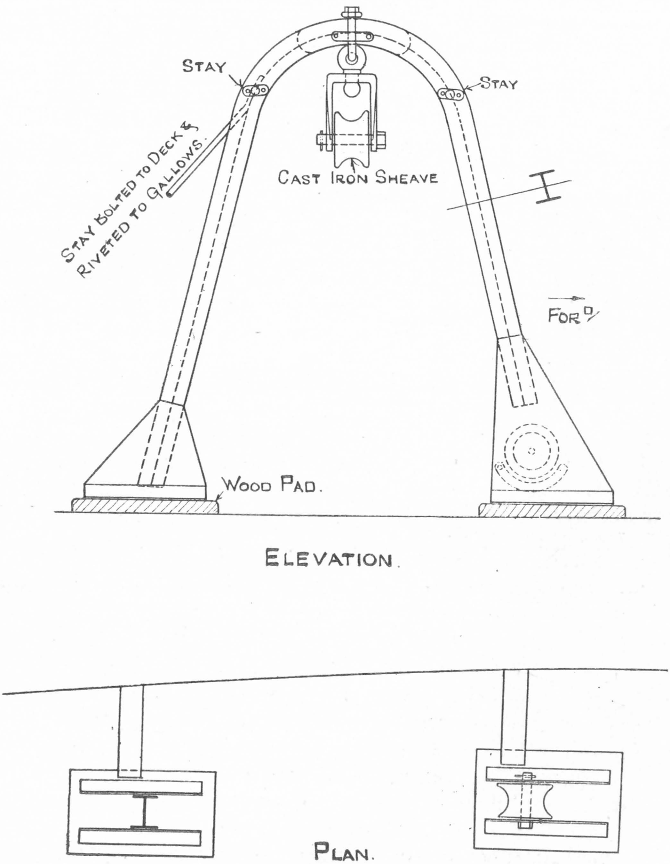

FIG. 17. GALLOWS AND BLOCK.

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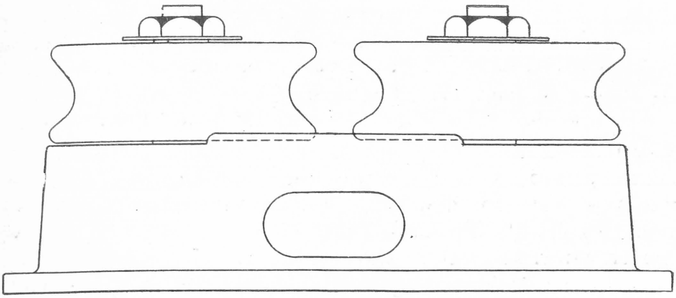

FIG. 18. CENTRE FAIRLEAD.

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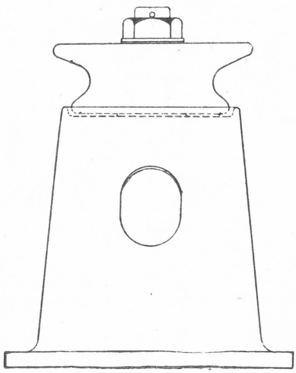

FIG. 19. SIDE FAIRLEAD.

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oft-times far above the normal breaking strain of a warp—to which a wire trawl warp is subjected. The strain seems occasionally to be more than the warp can be expected to sustain, but it speaks well for British wire that a wire trawl warp in constant use will give good service for sometimes eight to ten months.

When the operation of trawling is going to be commenced the vessel is manœuvred until the wind is on her beam and the net is then put over on the lee side. The forward otter board is lowered first and about 12 fathoms of the drag rope secured to the board paid out before the barrel with the other drag rope is put into operation. Then both ropes are run out together until the net is at a suitable distance from the ship. This is a point for the judgment of the skipper. After this has been settled the main barrels of the winch are put out of action and the drag ropes are pulled inboard, sideways, by means of a chain worked

from the winch drums, in order that they may be attached to the after towing bollard on the side of the vessel over which the net is being worked. The speed of the vessel when towing is generally between $2\frac{1}{2}$ and 5 knots.

In hauling the net on board, the above operations are carried out in the reverse order. When the net has been pulled alongside it is hoisted above the deck by tackle provided at the mast-head, and in this position the end of the pocket is unlaced and the fish permitted to fall into the deck ponds where they are sorted out and then transferred to the fish-room below.

A feature which is not often seen in other classes of vessels is the acetylene gas generator. This form of light finds great favour with trawlers, with whom lighting is a very important matter when hauling the trawl at night.

Steam trawlers may be divided roughly into three classes, viz. :—

(1) Small vessels for North Sea fishing, from 90 ft. to 100 ft. in length.

(2) Medium sized vessels for North Sea fishing and capable of trips to Iceland, from 100 ft. to 130 ft. in length.

(3) Large vessels for voyages to distant fishing grounds such as the Banks of Newfoundland, above 130 ft. in length.

Some of the small vessels have a sufficient coal supply to last from six to eight weeks, during which time they remain on the fishing grounds, and periodically deliver their catches to a "carrier"—a larger type of vessel—whose duty it is to go round collecting the fish from the individual vessels in the fleet and to deliver it at headquarters.

Particulars are given below of a small steam trawler :—

Length B.P.	92′ 0″
Breadth Mld.	21′ 6″
Depth Mld.	10′ 9″
Draught mean	9′ 3″
Displacement	255 tons.
Block Co-eff.	.488

The displacement is made up as follows :—

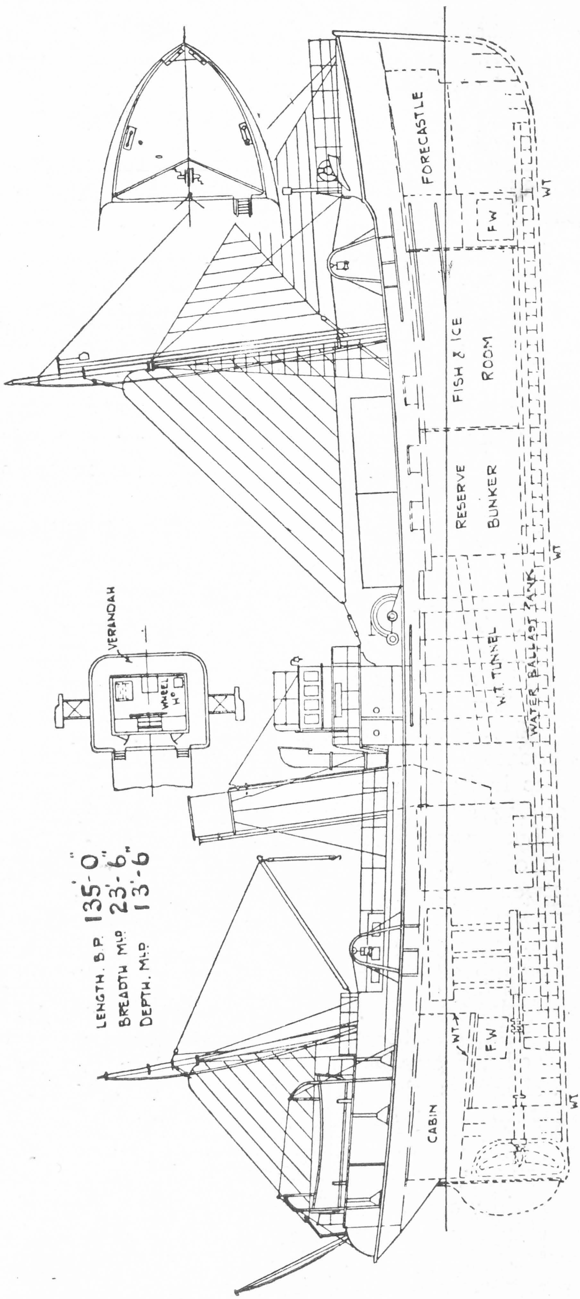
Hull and equipment	134 tons.
Machinery	51 ,,
Bunker Coal	49 ,,
Feed Water	7 ,,
Fresh Water	1.5 ,,
Ice	10 ,,
Crew and effects	2.5
Total	255.0 tons.

The General Arrangement and Midship Section of a typical large steam trawler are shown in Fig. 20 and 21 respectively. On reference to Fig. 20 it will be seen that the vessel has a raised quarter-deck extending from aft to forward of amidships, and is provided with a whale or turtle back forward. The turtle back greatly assists in keeping seas off the vessel, and at the same time affords protection for the crew when working at the fish. Commencing at the after end there is a mess room and cabin with accommodation for two officers and four hands; then the engine room, boiler room, coal bunkers, reserve bunker, fish and ice-room, store room and forecastle. The reserve bunker is used for coal on the outward trip and a tunnel is arranged under the main bunker so that the reserve bunker can be worked on the way out. On arrival at the grounds the reserve bunker is washed out and fitted with boards so that it can be filled with fish, while the athwartship and side bunkers supply fuel when the boat is actually fishing and for the return journey. A water-ballast tank for boiler feed purposes is arranged under the cross bunker.

The fish room is divided up into several compartments with vertical divisions, so that the different classes of fish can be kept separate, and horizontal shelves are fitted in them so that the bottom layers of fish shall not be spoilt by the weight of the fish above them. The fish are carried on these shelves, packed in ice to preserve them during the voyage home. The spacing of the shelves depends upon the kind of fish stored, as in the case of cod only single layers are permissible, and the shelves are therefore close together. All shelves and divisions are portable and interchangeable. The amount of timber required for these divisions is in itself no small item. For the better preservation of fish during long voyages some large trawlers have the shell, deck and bulkheads, surrounding the fish and ice-rooms insulated by means of several layers of compressed cork, with insulating paper between the layers or by means of silicate cotton, held in place by wood grounds and lining. This is especially valuable during the summer months. A few vessels have complete refrigerating apparatus and ice-making machinery fitted on board.

The deck ponds in the well forward are as already stated used for sorting out the fish after the pocket of the trawl net has been unlaced and emptied on the deck. These ponds are formed by wood divisions about 27″ deep and are held in position by sockets attached to the deck.

The scantlings of trawlers are usually about 10 to 20% in excess of Lloyd's requirements for an ordinary vessel of similar dimensions, in view of the greater stresses they have to withstand while trawling, and to enable them to withstand the peculiar treatment to which they are subjected when in harbour. When a fleet of trawlers return to port, the great point is to get the



LENGTH. B.P. 135'-0"
BREADTH MLD 23'-6"
DEPTH. MLD 13'-6"
VERANDAH
WHEEL Ho
FORECASTLE
F.W
WT
FISH & ICE ROOM
RESERVE BUNKER
W.T. TUNNEL
WATER BALLAST TANK
CABIN

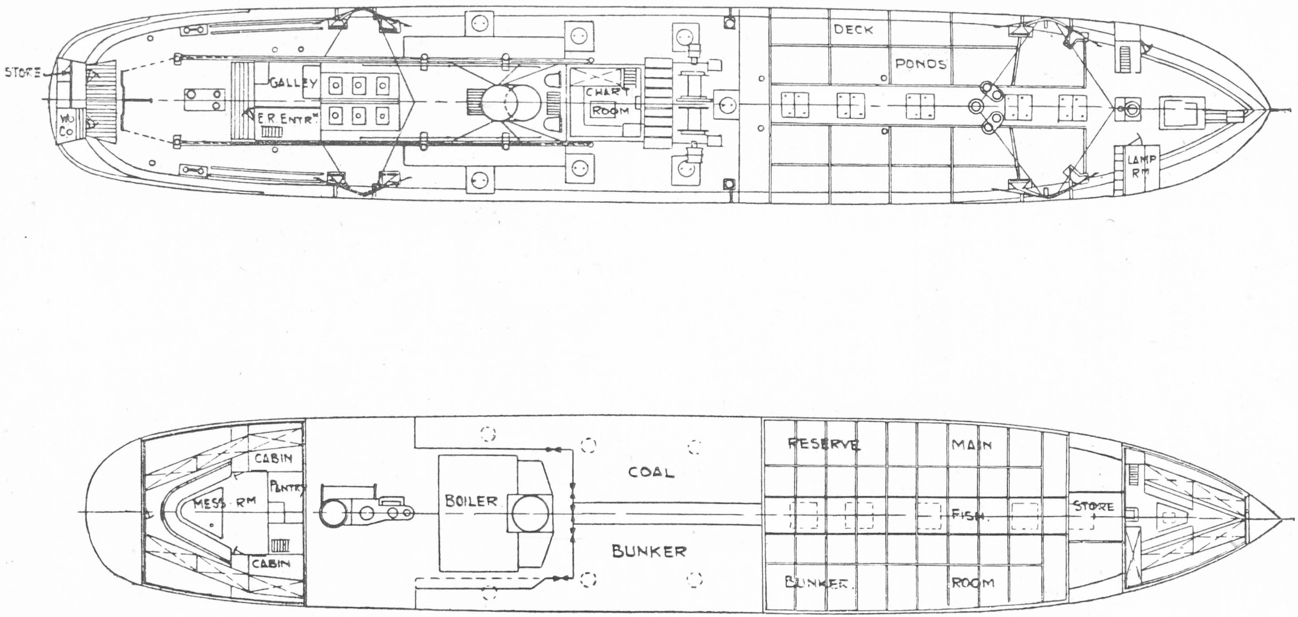


FIG. 20. GENERAL ARRANGEMENT OF A TYPICAL LARGE STEAM TRAWLER.

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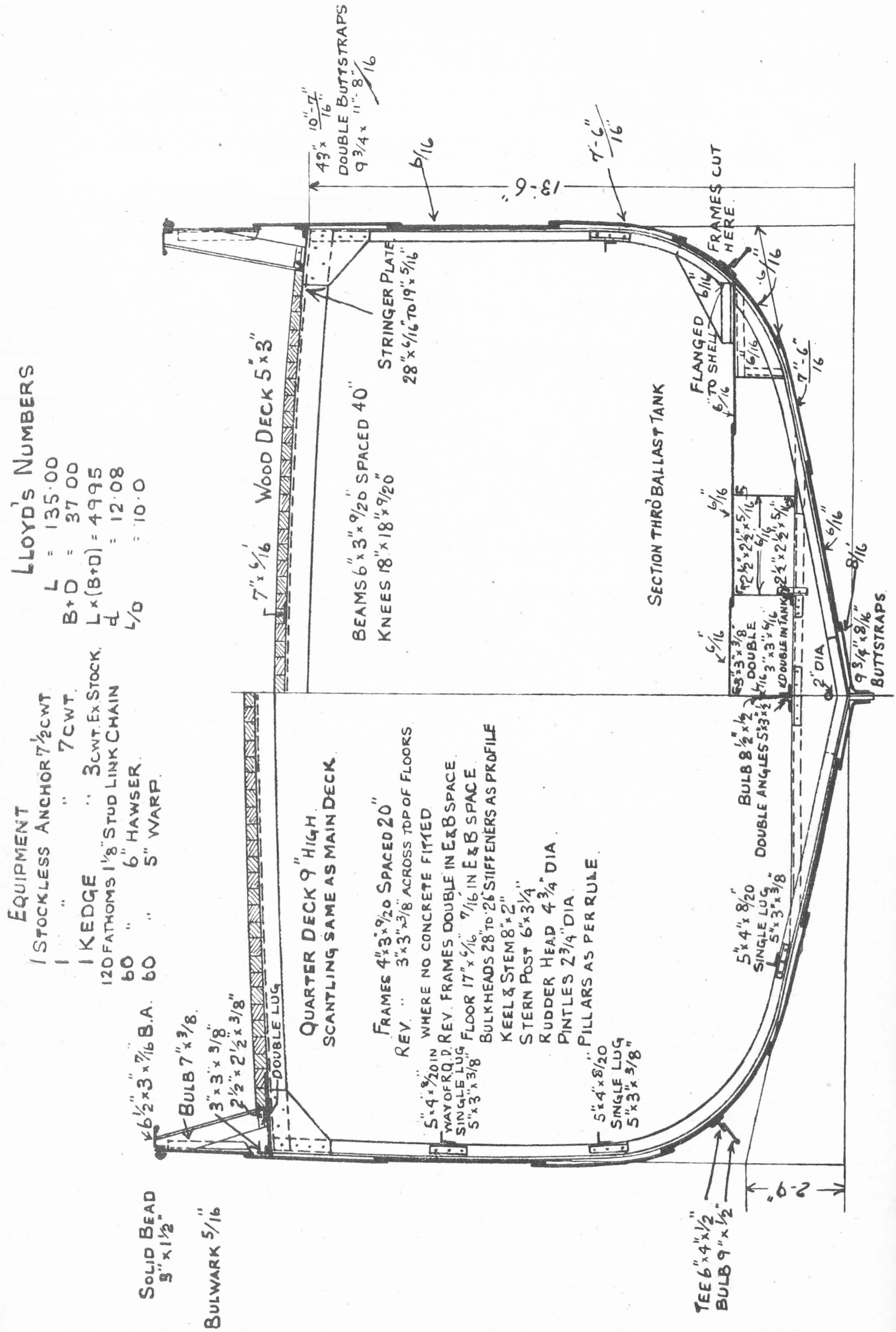

Fig. 21. Midship Section of a Typical Large Steam Trawler.

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catch ashore at the earliest possible moment, and the later arrivals simply "butt in" wherever they think they can see a possibility of making an opening between two other boats. This "butting in" process of making an opening where none previously existed, takes no account of mere paint; it is a question of actual strength of construction, and plating and framing will suffer if they are not strong enough. Fig 21 gives the scantlings for the trawler shown in Fig. 20, and shews also the water ballast tank under the coal bunker.

Further particulars of the vessel shown in Fig. 20 are given below.

Draught forward	10′ 0″
Draught aft	15′ 8″
Draught mean	12′ 10″
Displacement	600 tons.
Block Co-efficient	.52
Prismatic ,, ...	.605
Mid Area ,, ...	.36
Gross tonnage	345
Net ,, ...	135
Sheer Forward and Aft	4′ 3″

The displacement is made up as follows :—

Hull and Equipment	238 tons.
Machinery	105 ,,
Bunker Coal	190 ,,
Feed Water	22 ,,
Fresh Water	6 ,,
Ice	35 ,,
Crew and effects	4 ,,
Total	600 tons.

Propelling machinery for a trawler of above type generally consists of a set of triple expansion engines, having cylinders about $12\frac{1}{2}$, 23, and 37″ in diameter, with a stroke of 26″ and at a speed of 112 revolutions, developing about 575 I.H.P. The speed of the vessel at this power would be about 11 knots. The high and medium pressure cylinders are fitted with piston valves, and the low pressure with a slide valve. The main bedplate is of cast iron, carrying brass bearings lined with white metal. The crankshaft is of the built type, with steel webs shrunk on and dowelled. The connecting rods are of the forked type, having double brasses at the top and large brasses lined with white metal at the bottom. Steam reversing gear of the all-round type is fitted with double bar link motion and eccentrics with large surfaces. Air, feed and bilge pumps are worked by levers off the h.p. crosshead and have slipper guide. The condenser, of the surface-condensing type, is a separate casting, carried on brackets on the m.p. and l.p.

columns. A separate 5″ centrifugal circulating pump is provided with piston valves and balanced cranks, discharging through the condenser. A special ejector is fitted to the condenser bottom, which, used in conjunction with the centrifugal pump, enables the exhaust steam from the winch to be condensed when the main engines are stopped. The thrust block is of the horse-shoe type, with separate white metal liners to both ahead and astern faces. Steam is generally supplied by a single-ended cylindrical boiler about 14′ 0″ diameter and 10′ 6″ long with a working pressure of 200 lbs. per square inch.

A new form of otter board, patented in all countries, has been introduced by Dr. Oertz of Hamburg. The particulars given below of this new otter board have been taken from the "Shipbuilder." A curved or bent form, as shown in Fig 22, is adopted instead of the usual flat board hitherto employed. The effect of the flat boards was to open the mouth of the net to a certain degree. New experience with aeroplane wings, sails and other similar agents, show that these are most effective if not flat but somewhat curved. Dr. Oertz has applied such experience to otter boards with complete success. Experiments have shown that the efficiency of the otters in opening the trawl net is augmented 50 per cent. if curved otters are used. A complete series of tests was made in the Berlin experimental tank, and the best form found in this way. Later, full scale experiments were made with a small trawler on the Elbe. It was found that the curved otters open the trawl net immediately it is placed in the water, and the tank result was confirmed that the mouth of the trawl was opened about 50 per cent. wider than with the flat otters hitherto used at the same trawling speed. The new form of otter also ensured more even trawling, and kept the mouth of the trawl open at a very low speed. At these trials the best angle of the otters to the direction of trawling was investigated and found to be 35 degrees.

In order to make his invention practicable for otters of the old type, Dr. Oertz also tried otters of a bent angular form. He found that the good effect of curved otters could be approximated to with angular otters. Flat otter boards can be very simply altered to an angular form as shown in Fig. 23. The experiments have also brought out some interesting facts about the general proportions of otters. The results show that depth is the chief factor for effectiveness, length having a minor influence. In order to avoid overturning, however, the length should be about 1.5 to 1.6 times the depth.

Reference has already been made to the classes of steam trawlers, and in this connection it is of interest to note that the largest steam trawler afloat is the "Patrie," built by Messrs. Cochrane & Sons, Ltd., Selby. The vessel is intended for cod-fishing on the Banks of Newfoundland and in Icelandic waters. The cod are salted on board by the crew; and are afterwards sold

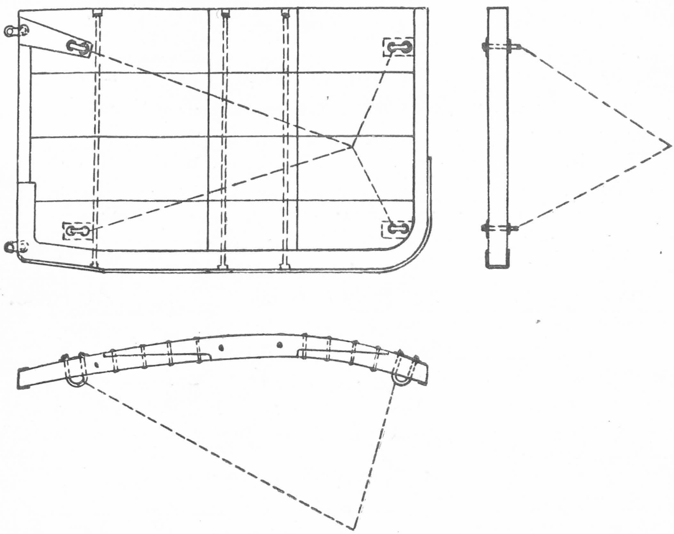

FIG. 22. PATENT OTTER BOARD OF CURVED FORM.
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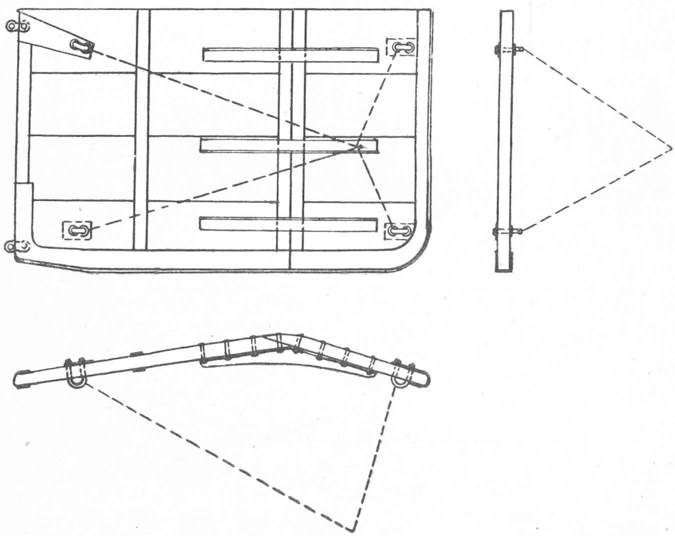

FIG. 23. ANGULAR OTTER BOARD.
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as dried cod, for which there is a market all over the continent. For the above purpose the vessel takes out about 300 tons of salt. Further particulars of this large trawler are given below.

Length B.P.	200′ 0″
Breadth Mld.	32′ 0″
Depth Mld.	16′ 0″
Displacement	1,720 tons (about).
Block Coeff.	.65
I.H.P.	800
Officers and Crew	45

Trawlers are a type of ship which are driven at a speed much beyond the economical limits. In this class the resistance begins to increase very rapidly at about $\frac{V}{.9\sqrt{L}}$. and since they are driven at considerably higher speeds than that, there is a great expenditure of power in wave-making. The nature of their trade,

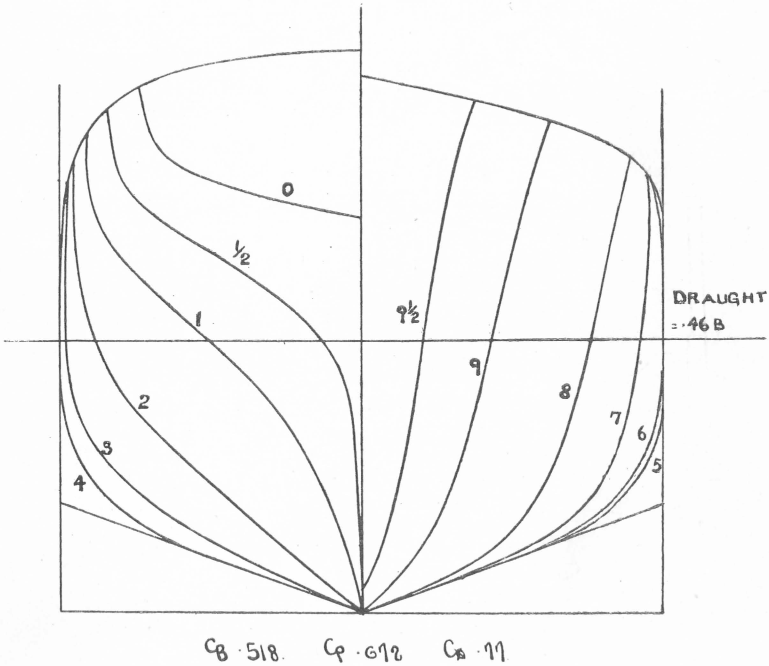


FIG. 24. BODY PLAN OF TRAWLER.

however, demands certain proportions and capacity, and economy in propulsion is of secondary importance. The body plan of a trawler is given in Fig. 24.

The height of the Centre of Gravity above base of trawlers in the light condition (hull and machinery) is about ·75 depth to main deck.

In estimating I.H.P. by Admiralty Constant, C may be taken generally as 130.

$$\text{I.H.P.} = \frac{W^{2/3} \times V^3}{C}$$

When W = Displacement in tons.
V = Speed in knots.

The weight coefficients of a trawler may be taken as follows :—

Weight of hull $= N \times C_h$
Weight of steel $= N \times C_s$
Weight of wood and fittings $= N \times C_w$

$$\text{When } N = \frac{L \times B \times D}{100}$$

and $C_s = .35 \quad C_w = .17 \quad C_h = .52$

Under the Merchant Shipping Act, and under the Sea Fisheries Act, all British sea fishing vessels are compelled to show letters and numbers signifying their Port of Registry. Table I. annexed gives the port distinguishing letters for Scotland and England.

TABLE I.

PORT DISTINGUISHING LETTERS FOR FISHING VESSELS.

Distinguishing Letters.	Port of Registry.	Distinguishing Letters.	Port of Registry.
A	Aberdeen	LH	Leith
AB	Aberystwith	LK	Lerwick
AG	Ardrishaig	LN	Lynn
AR	Ayr	LO	London
BD	Bideford	LT	Lowestoft
BE	Barnstaple	M	Milford
BF	Banff	ME	Montrose
BK	Berwick	OB	Oban
BM	Brixham	P	Portsmouth

Distinguishing Letters.	Port of Registry.	Distinguishing Letters.	Port of Registry.
BRD	Broadford	PD	Peterhead
BT	Bridport	PH	Plymouth
CN	Campbeltown	PN	Preston
DE	Dundee	PZ	Penzance
DS	Dumfries	R	Ramsgate
FD	Fleetwood	RX	Rye
FE	Folkestone	SH	Scarborough
FR	Fraserburgh	SM	Shoreham
FY	Fowey	SN	North Shields
GK	Greenock	SS	St. Ives
GN	Granton	SSS	South Shields
GY	Grimsby	SY	Stornoway
H	Hull	TH	Teignmouth
HL	Hartlepool	WA	Whitehaven
INS	Inverness	WK	Wick
K	Kirkwall	WY	Whitby
KY	Kirkcaldy	YH	Yarmouth

MOTOR TRAWLERS.

The problem of the motor trawler is not nearly such a simple one as many would have us believe. Among the chief problems are the frequent occasions on which it is necessary to run the engine dead slow, the necessity for a single screw, and the extraordinary demands made upon the winch.

The question of the trawl winch drive is not so simple as would at first appear, because when the trawler is hauling in her gear in a heavy sea, the pitching and rolling of the vessel causes great variations in the strain on the trawl warps, amounting to probably 90 per cent. according to whether the winch is racing away, or slowed down almost to a stop. There are two solutions :—

1. A separate motor winch on deck or below.
2. A drive from the main engine to the winch shaft.

The second may probably be the best, as the main engine is really never required to develop full power when the otter boards are out, but only sufficient to keep way on the vessel.

If the engine is fitted below deck it would not affect the fish holds, as the space taken up by the main engine and the motor winch would still be considerably less than that needed for a steam engine and boiler, and this arrangement would have the advantage of leaving much more deck space for sorting out the fish. A powerful clutch would be required, adjusted so that it would slip after a predetermined strain on the wire was reached, and thus save it from breaking.

An effort to solve the problem has been made in America by employing the electric drive, the vessel being an ordinary 10 knot trawler having a single screw.

The principal particulars of the vessel are as follows :—

Length on load waterline	140ft. 0in.
Beam	24ft. 3in.
Mean draught	11ft. 9in.
Displacement	500 tons.
Cruising radius at 10 knots ...	6,000 miles.

The propelling machinery consists of two eight cylinder four cycle Nelseco Diesel engines, rated at 240 B.H.P. at 350 R.P.M. The engines are direct coupled to two generators, each generator being rated at 165 kilowatts at 125 volts. For propulsion, these two generators are run in series and supply power to the main motor, which is rated at 400 B.H.P. at 200 R.P.M. The rated voltage on the motor is thus 250 volts. If so desired, the main motor can be run at any reduced voltage, and in case the maximum impressed voltage on the motor does not exceed 125 volts, then one of the generator units can be shut down entirely and the motor operated entirely from the other generator unit. Connections are supplied and means of adjustment are provided so that any range of voltage and current can be supplied to the main motor and the load divided up on the main generating sets as desired.

The motor for the winch is a 125 volt machine and takes its power from either of the main generating sets. All the auxiliary power and lighting circuits on the vessel are of 125 volts, so that power for either the lights or the auxiliary machinery can be taken from any one of the main generating units even though they may be supplying power to the propelling motor.

The speed of the vessel on trial was a little over 10 knots at 195 R.P.M. The propeller is of cast iron, three bladed, with a diameter of 7 ft. 10 in. and a pitch of 5 ft. 8 in. The fuel consumption at full power was 30 gallons per hour. On trial, the motor went right over from full ahead to full astern in 15 seconds.

There are a few motor trawlers in use and the progress of the latest of these will be followed with interest. So far it would seem that nothing sufficiently convincing has yet been produced.

Fishing concerns owning large fleets of boats as well as the owners of single vessels, realise the coming of the motor but do not fully appreciate the present satisfactory stage of development to which high powered engines have been brought. They want a solution of how to kill high running costs and are waiting to be convinced in the matter of economy.

The semi-Diesel engine is more likely to be used than the full Diesel because of its lower initial cost and simplicity.

Chapter 3.

HERRING DRIFTERS.

The method of fishing known as "drifting" or "driving" is followed by steam and sailing vessels, and is the principal method employed for the capture of fish—chiefly herring, mackerel, pilchards and sprats—which at certain times swim near the surface. Drifting is extensively pursued by steam vessels, and the magnitude of its employment in the herring industry may be witnessed at Lerwick in the early summer, and later in the year at Yarmouth, when as many as a thousand steam and kindred craft may be seen, forming an almost solid mass in the river. Such sights as this, and the fish docks at Grimsby, Fleetwood, Hull, Aberdeen, and at other places, enable any beholder to comprehend the extent to which the British fishing industry has grown. The steam drifter has largely taken the place of the sailing drifter and will undoubtedly continue to do so. As an illustration of the advantage the steam drifter has over the sailing drifter, it is no unusual thing to hear of cases where both vessels have hauled their nets close to each other, the former has then steamed to market, landed her catch, sold, cleaned up, taken in stores, and stood out to sea, meeting the sailer still on her way to a market with often falling prices. There are at least 1,300 steam drifters in the United Kingdom. The term "Drift Net Fishing" arises from the fact that these nets are not drawn through the water, but are allowed to drift or drive with the tide, in a more or less perpendicular position. The period allowed for the nets to drift is governed by the quantity of herring in the neighbourhood, the state of the tide, or the condition of the weather. Other things being equal, the nets usually ride out one tide. Speaking generally, the nets are shot so as to ride the whole tide, either ebb or flow, in which case the distance traversed by the nets is ten or twelve miles. Occasionally the nets are shot at half tide, and in this case they drift say five miles and the same distance, more or less, back, thus ending at approximately the starting point.

The nets are maintained, in a more or less perpendicular position, by reason of the weight of the warps, which are attached to the sole ropes by means of seizings, while the top ropes are attached to the pallets by the strop or buoy ropes, as shewn in Fig. 25, which has been kindly supplied by the Gourock Ropework Co., Ltd. The nets are sunk to any depth by either shortening or lengthening the buoy ropes, and when drifting for herring the top of the net is generally from 2 to 3 fathoms below the surface. In drifting for mackerel the upper edge of the net is kept close to the surface.

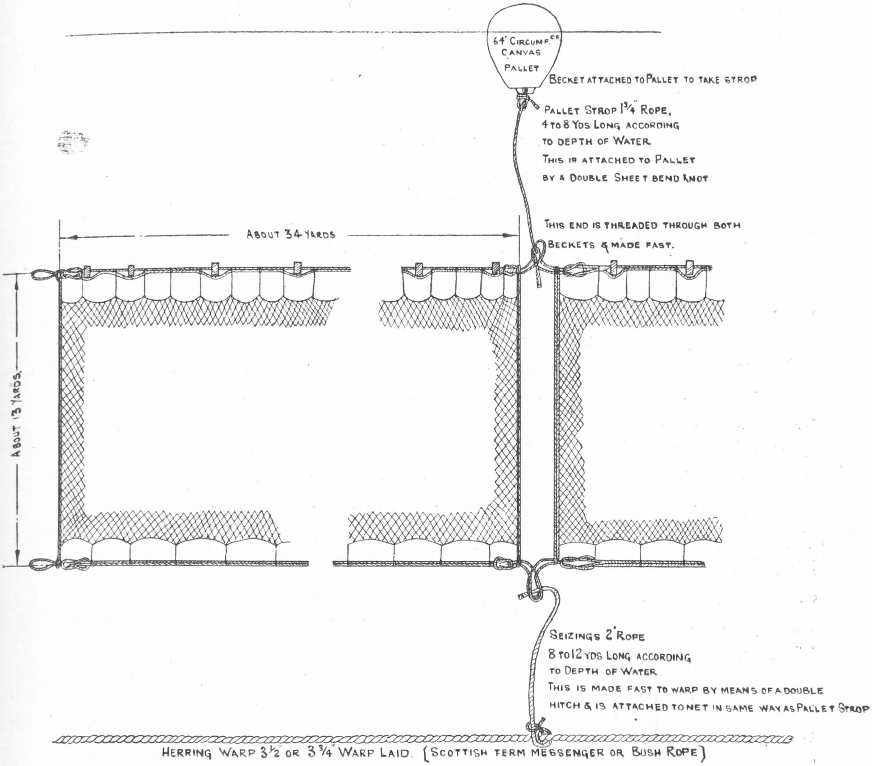


FIG. 25. DRIFT NET.

A "fleet" of nets when shot consists of from 70 to 90 nets, each measuring when in use about 34 yards long and 13 yards deep; the whole may be as much as two miles or more in length.

When the operation of shooting the nets commences, the vessel steams slowly to leeward, keeping the nets clear of the propeller. The nets are "shot" over a roller attached to the rail of the vessel. As the nets go over, they are attached to the warp (which simultaneously runs out from the capstan) by means of the seizings, and at the same time other members of the crew attach the buoys to the top of the net by means of the buoy ropes.

The warps have eyes spliced in each end, and are lashed together by lengths of small rope (18-thd. Manilla) generally called "Bend Lashings."

When the whole fleet of nets is out, the end of the last warp is made fast to the ship and the vessel comes round head to wind and rides to the fleet as to a sea anchor. The foremast is almost invariably lowered in order to make the vessel ride more easily

and to decrease wind resistance. If the weather suddenly turns bad the Coir Tissit is used. This is attached to the warp and made fast to the ship. It is used for what is known as "Hanging on to the Nets" in a gale, and coir is preferred because it has more spring in it.

The fish swimming in shoals or schools, strike against the nets and are entangled by their gills in the meshes, which, in the case of the herring nets, number from 30 to 34 to the yard. Mackerel nets have from 25 to 30, pilchard nets about 36, and sprat nets about 70 meshes to the yard.

Hauling the nets is a reversal of the shooting process. The warp is put on to the capstan while the crew pull on the net ropes. As the buoys come in they are unhitched and so also are the seizings, holding the nets to the warp.

During the process of hauling, as many as possible of the herring are shaken into the hold, but many still remain "meshed" in the net. The nets are therefore "tricked" over again, generally during the journey from the fishing ground to the port.

Shooting the nets occupy about 45 minutes. Hauling, anything from three to six hours. This latter operation is governed by the quantity of herring, the condition of the nets, or the state of the weather.

The general arrangement of a typical herring drifter built by Messrs. Cochrane & Sons, Ltd., of Selby, to whom the writer is indebted for the use of the plans and the leading particulars, is shown in Fig. 26. The propelling machinery and bunkers occupy the greater part of the ship's length up to amidships. Coal is carried in a cross bunker and in wing bunkers abreast the boiler. Forward of the cross bunker is the fish room and net room. The fish room is divided up into several compartments with vertical divisions. Salt is carried in some of these divisions so that if the catch is too small to be worth while taking to harbour at once, it may be salted on board, and landed later on.

Forward of the net room and at the sides of the ship, boiler feed tanks are located.

Accommodation for the crew is arranged on lower deck flats at the ends of the vessel. There are two berths forward and eight berths aft. A berth is also fitted in the wheel-house. The galley is placed on the upper deck at the aft end of the engine casing.

The chain locker is arranged in the fore peak beneath the crew's accommodation. The anchors are stowed on deck, being put in or outboard by means of an anchor davit. Two wood pole masts are fitted which serve to carry fore and aft sail.

The scantlings of the vessel, which are shown on the midship section, Fig. 27, more than comply with the requirements of

Lloyd's 100 A.1 class. Ordinary floors are fitted throughout, there being no double bottom. A steel bulwark is fitted right round the upper deck.

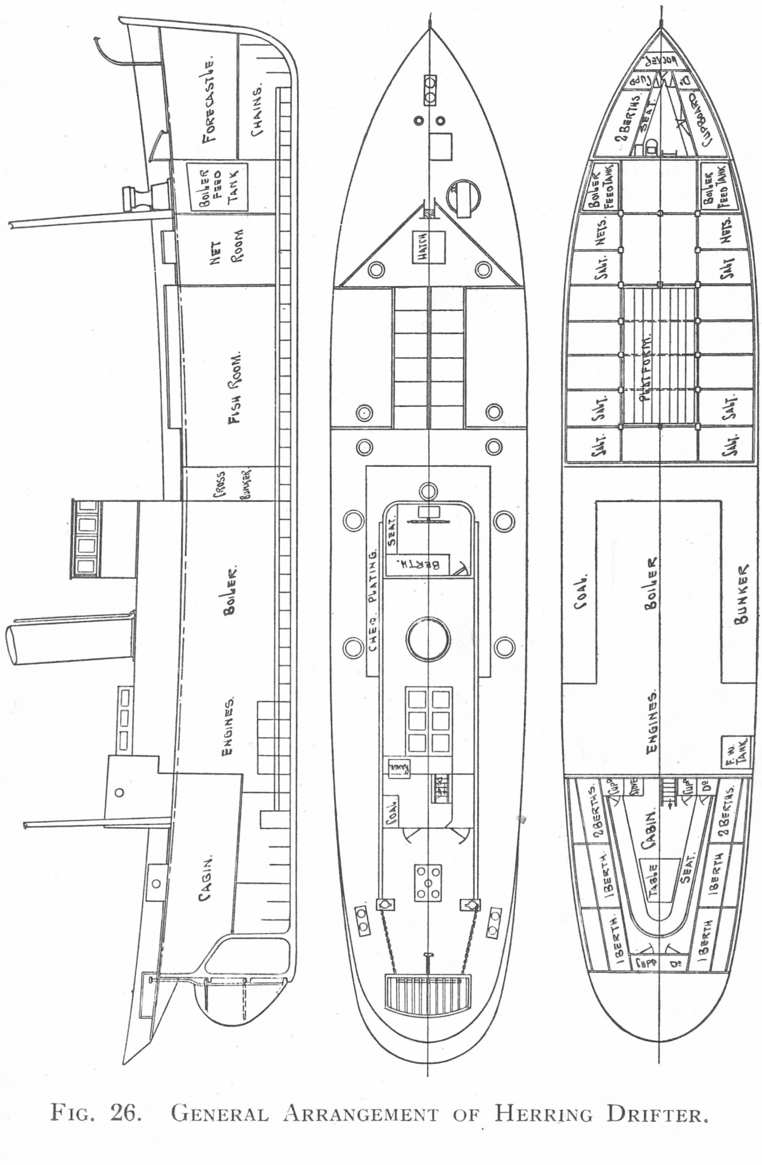


FIG. 26. GENERAL ARRANGEMENT OF HERRING DRIFTER.

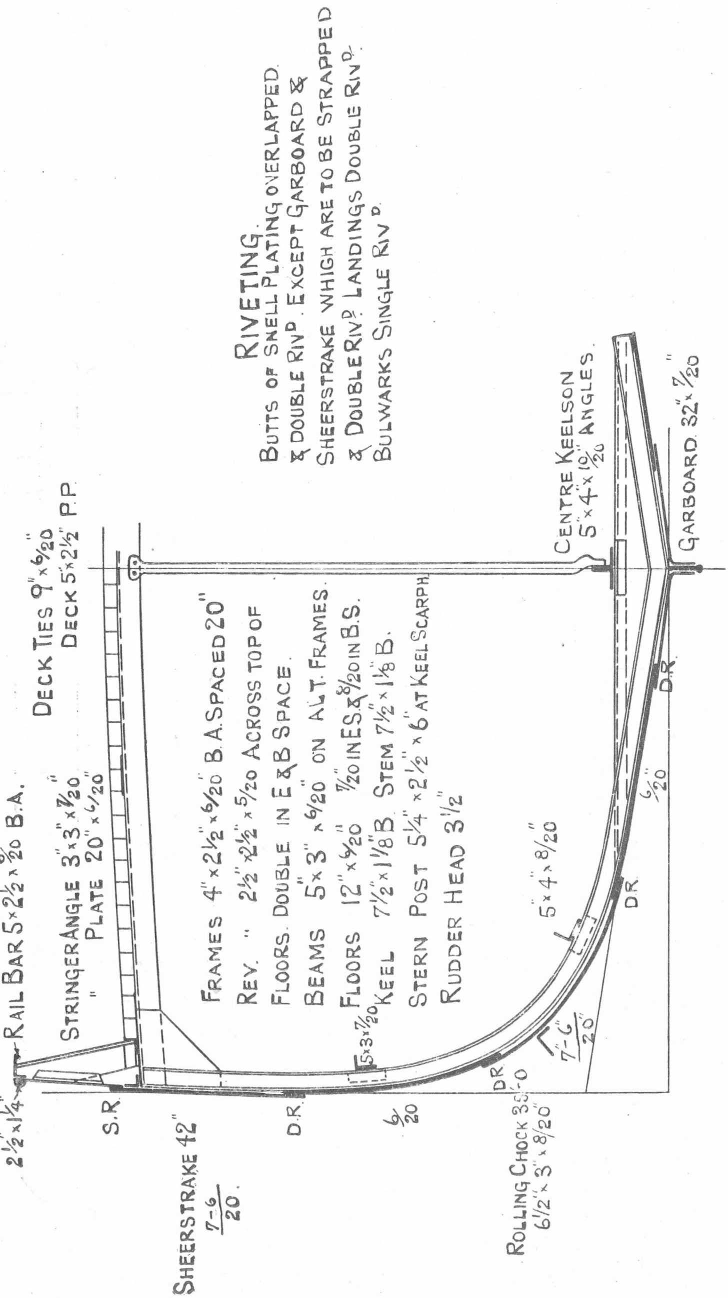


FIG. 27. MIDSHIP SECTION OF HERRING DRIFTER.

The equipment of anchors, cables and warps is as follows :—

2 Bower anchors, stockless, $4\frac{1}{2}$ cwts. each.
1 Kedge anchor, ex. stock, 2 cwts.
60 fathoms stud link cable, 13/16″.
60 fathoms hemp hawser, $5\frac{1}{2}$″.
60 fathoms hemp warp, 3″.

Particulars of the vessel shown in Fig. 26 are given below :—

Length B.P.	88′ 0″
Breadth Mld.	19′ 0″
Depth Mld.	9′ 6″
Draught forward	5′ 0″
Draught aft	10′ 0″
Draught mean	7′ 6″
I.H.P.	220
Displacement	170 tons.
Block Coefficient	.508
Prismatic ,, ...	.614
Mid. area ,, ...	.828
Gross tonnage	102
Net ,, ...	47

The displacement is made up as follows :—

Hull and equipment	80 tons.
Machinery	55 ,,
Bunker coal	26 ,,
Feed water and fresh water	5 ,,
Crew, provisions and stores	2 ,,
Salt	2 ,,
Total	170 tons.

The propelling machinery consists of a set of compound expansion engines having cylinders $12\frac{1}{2}$ and 26 in. in diameter with a stroke of 18 in. Steam is supplied by a single ended cylindrical boiler 10′ 3″ in diameter by 10′ long, and designed for a working pressure of 130 lbs.

In estimating I.H.P. by Admiralty Constant, C may be taken generally as 115.

$$\text{I.H.P.} = \frac{W^{2/3} \times V^3}{C}$$

where W = displacement in tons.
V = speed in knots.

The weight coefficients of a drifter may be taken as follows :—

$$\begin{aligned} \text{Weight of hull} &= N \times C_h \\ \text{Weight of steel} &= N \times C_s \\ \text{Weight of wood and fittings} &= N \times C_w \end{aligned}$$

$$\text{where } N = \frac{L \times B \times D}{100}$$

and $C_s = .34$, $C_w = .18$, $C_h = .52$.

CHAPTER 4.

SEINE NET FISHING VESSELS.

The method of using Seine nets is an old form of fishing which has recently been re-introduced by the Danes. The method is particularly suitable for the smaller craft intended to operate at moderate distances from their base and in fair weather, such as is prevalent in the North Sea during the summer months. Fishing can only be effectively carried on when the tide is practically dead.

The chief features of the Danish seine are :—

(1) Superior fishing capacity to that of the trawl.
(2) Cheaper working costs.
(3) Better selective action of the net.

The smallest fish escape unharmed and the large fish are secured in a better condition than is possible from trawl nets.

For working the Seine net a steam winch and coiler is used. The winch and coiler is arranged sideways so that fishing can be carried on from either side of the vessel, but usually proceeds from one side only. The net, which is very light and provided with light cork floats, is put overboard from the stern. When operating, a buoy is first put out and then about 1,000 fathoms of light warp is payed out from the coiler. Next the net is put out and then about another 1,000 fathoms of warp. In the meantime the vessel follows a triangular course to pick up the buoy after paying out the second length of warp, and the two warps are then hauled in and coiled by the winch and coiler. This method is indicated in Fig. 28, and the anchoring of the buoy in Fig. 29. The time occupied in shooting and hauling is about $1\frac{1}{4}$ hours.

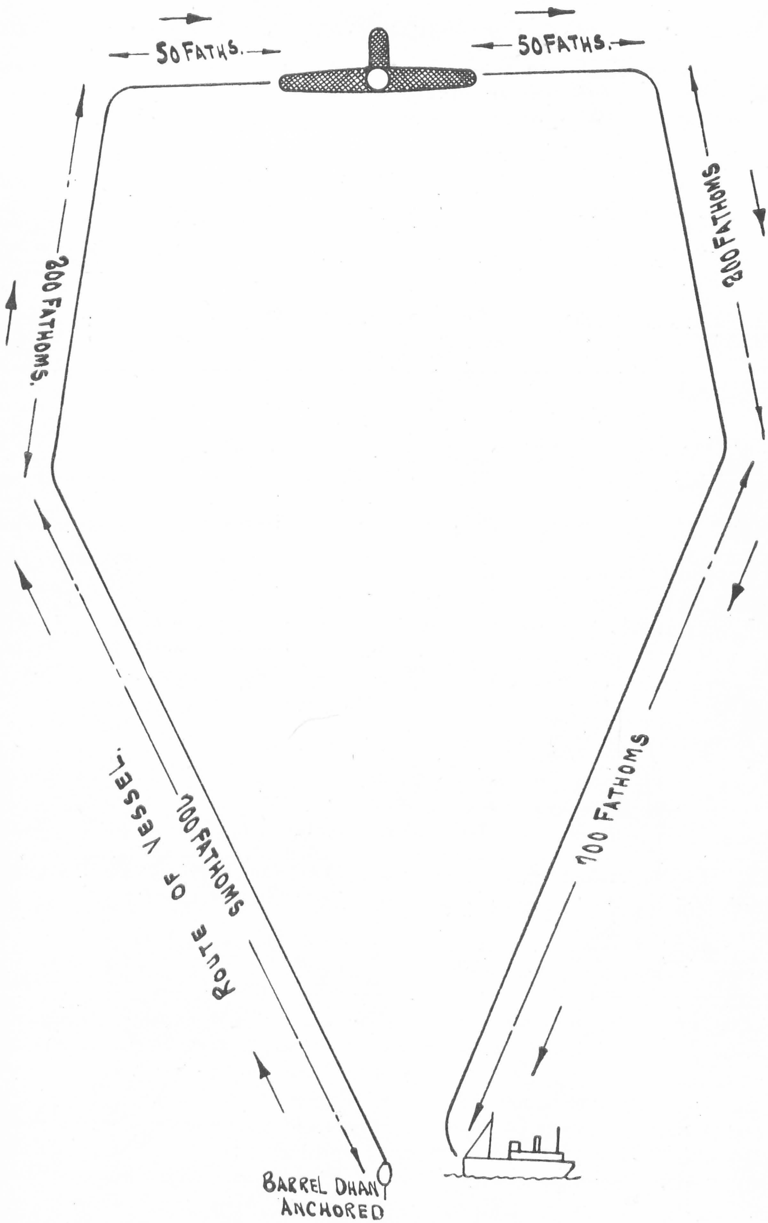


FIG. 28. SEINE NET—METHOD OF SHOOTING.

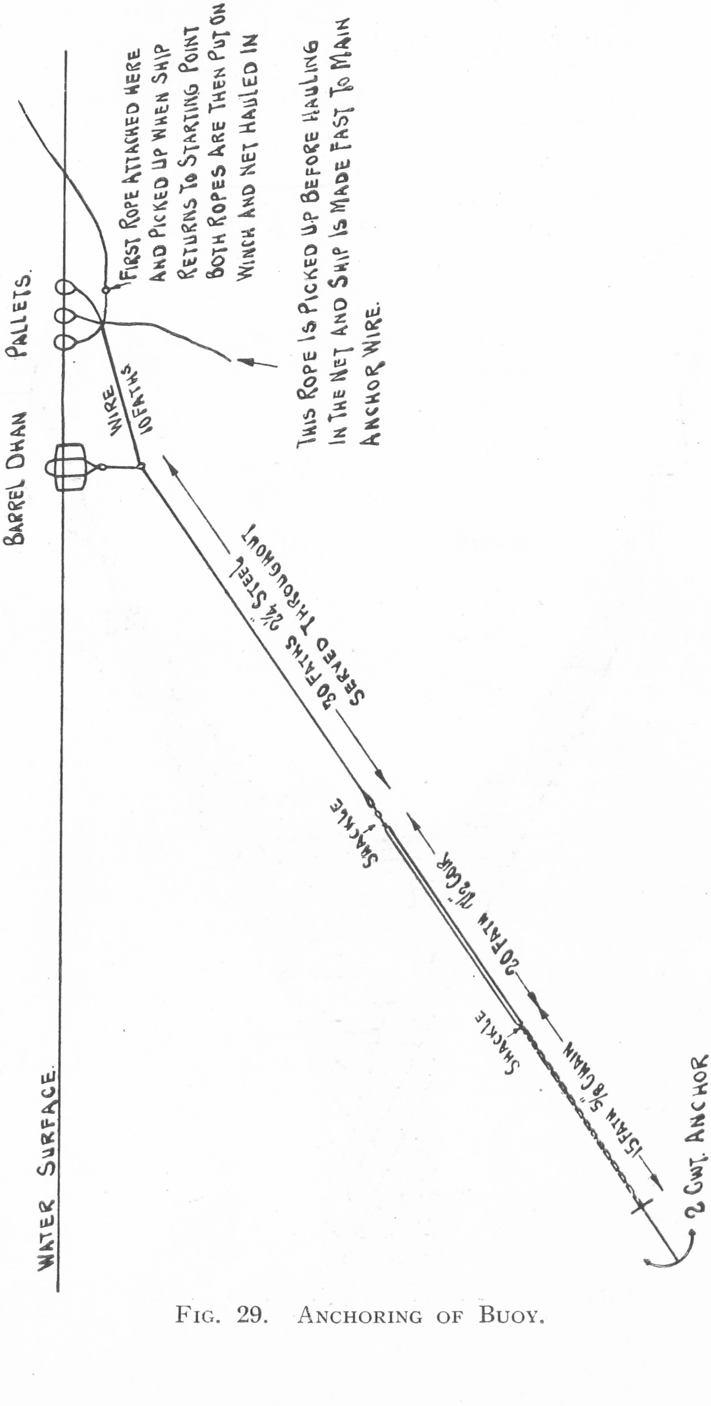


FIG. 29. ANCHORING OF BUOY.

The method of seining employed by British fishermen is that which can be handled by one vessel. New systems, however, are subject to rapid improvement, and already a French expert has experimented to advantage with two steamers of about 56 ft. in length. The Frenchman has used two vessels in the English Channel, fishing together, one being moored head to the tide, while the other expanded the ropes and the net across the tide in a straight line. This being done, the vessels steered against the

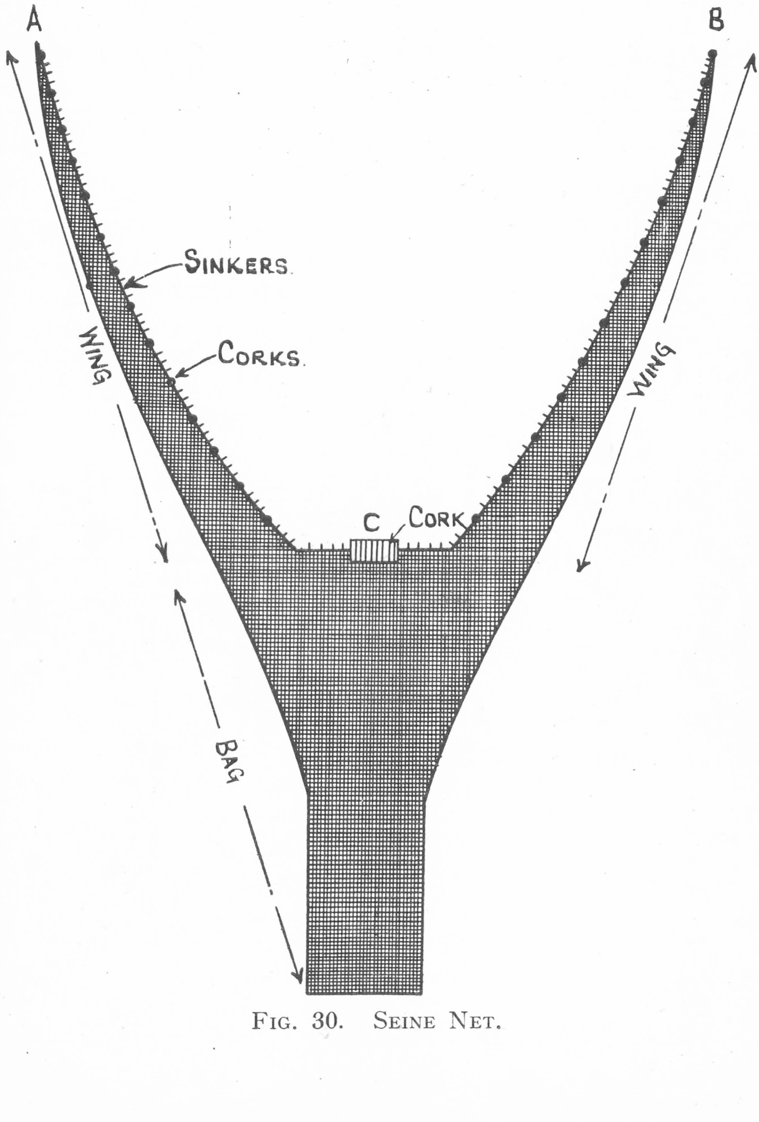
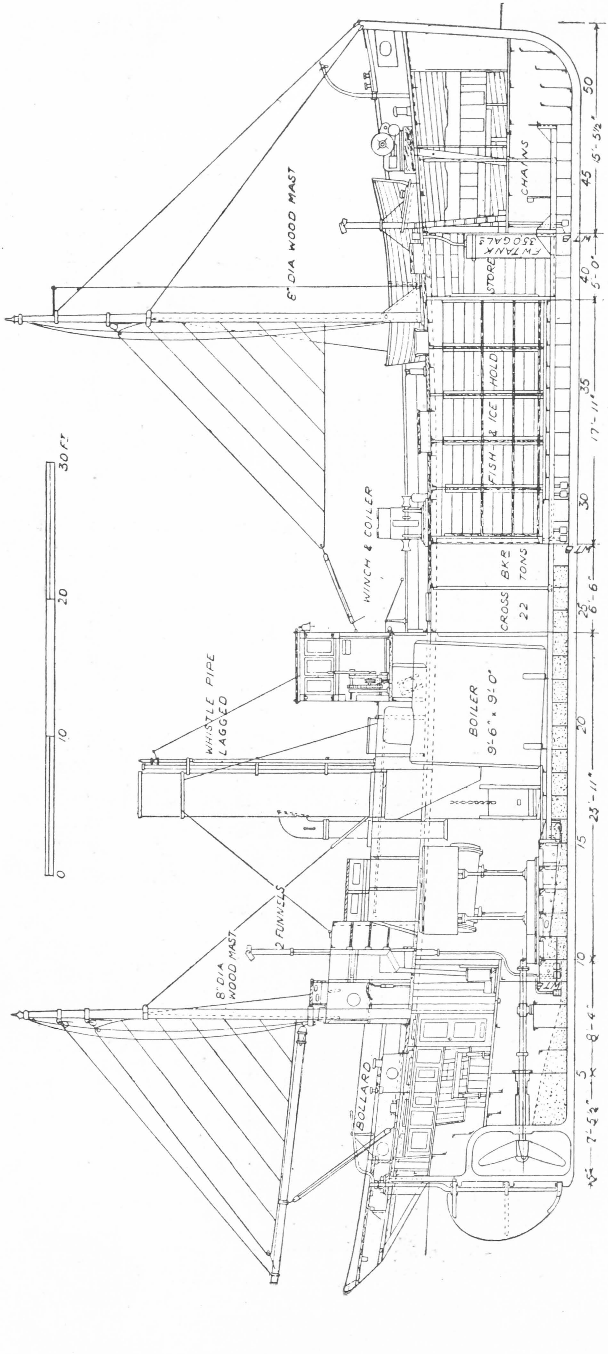


FIG. 30. SEINE NET.



8" DIA WOOD MAST
WINCH & COILER
WHISTLE PIPE LAGGED
2 FUNNELS
8" DIA WOOD MAST
BOLLARD
BOILER 9'-6" x 9'-0"
CROSS BKR 22 TONS
FISH & ICE HOLD
STORE
F.W TANK 350 GALS
CHAINS
0
10
20
30 FT

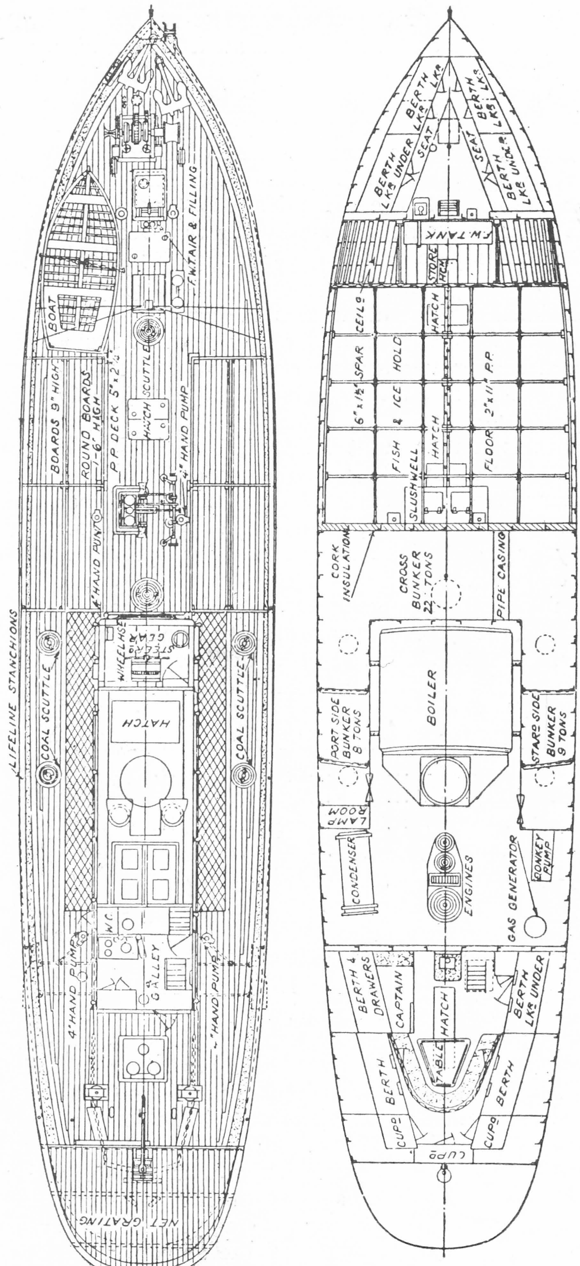


FIG. 31. GENERAL ARRANGEMENT OF SEINE NET FISHING VESSEL.

tide for ten minutes and then met. The rope was thrown from one boat to the other by means of a stick loaded at one end with a lead ball. When both ropes were on board one vessel they were hauled along with the net in the ordinary way. This plan is claimed to be more efficient than other methods employed, with the additional advantage that the area of the seine described by the two vessels is sometimes greater than that described by the ordinary method with the same length of ropes. Though only one net is used at the same time by the two vessels, it is claimed that the catch is five times greater than that of the ordinary system.

The seine net is semi-circular in form, and as it is kept stationary while the ship is under way prior to hauling in, power is not required for towing the net as in the case of a trawler. The net is shown in Fig. 30, which has been kindly supplied by the Gourock Ropework Co., Ltd.

The net is not brought inboard, but the cod end is picked up and the fish "diddled" out of the cod end.

A seiner carries a crew of eight men—skipper, mate, two drivers, three deckhands and a cook. The crew are almost incessantly at work while at sea, fishing operations in summer lasting from dawn till dusk.

Specially designed vessels to suit this method of fishing have been built and the general arrangement of one of these constructed by Messrs. Cochrane & Sons, Ltd., of Selby, is shown in Fig 31. The blocks for Figs. 31 and 32 have been kindly supplied by the "Shipbuilder."

The leading particulars of the vessel are as follows :—

Length B.P.	85′ 0″
Breadth mld.	19′ 0″
Depth mld.	9′ 9″
Gross tonnage	97
Net ,, ...	35

The propelling machinery and bunkers occupy the greater part of the ship's length up to amidships. Coal is carried in a cross bunker with a capacity of 22 tons and in wing bunkers abreast the boiler, the port side bunker having a capacity of 8 tons, and the starboard side bunker a capacity of 9 tons. Forward of the cross bunker is the fish and ice hold, which is sub-divided and ceiled as usual in trawlers. Portable partitions and shelves are provided, the former supported by stanchions in the form of a channel bar at each side of the partition. The usual sorting pounds are provided on the deck above.

Forward of the fish hold is a store, in which is also located a fresh-water tank with a capacity of 350 gallons.

Accommodation for the crew is arranged on lower deck flats, built into the peaks at the ends of the ship. Forward there are berths for four deck hands and aft for the captain and three men,

making a total complement of eight in all. The galley is placed on the upper deck at the after end of the engine casing.

The chain locker is arranged in the fore peak beneath the crew's accommodation. The anchors are stowed on deck, being put in or outboard by means of an anchor davit. A steam windlass is installed forward. Steering is effected by hand from the wheelhouse through an arrangement of chains, rods and sheaves, and also by a hand tiller directly attached to the rudder head. A small boat is provided on the deck forward.

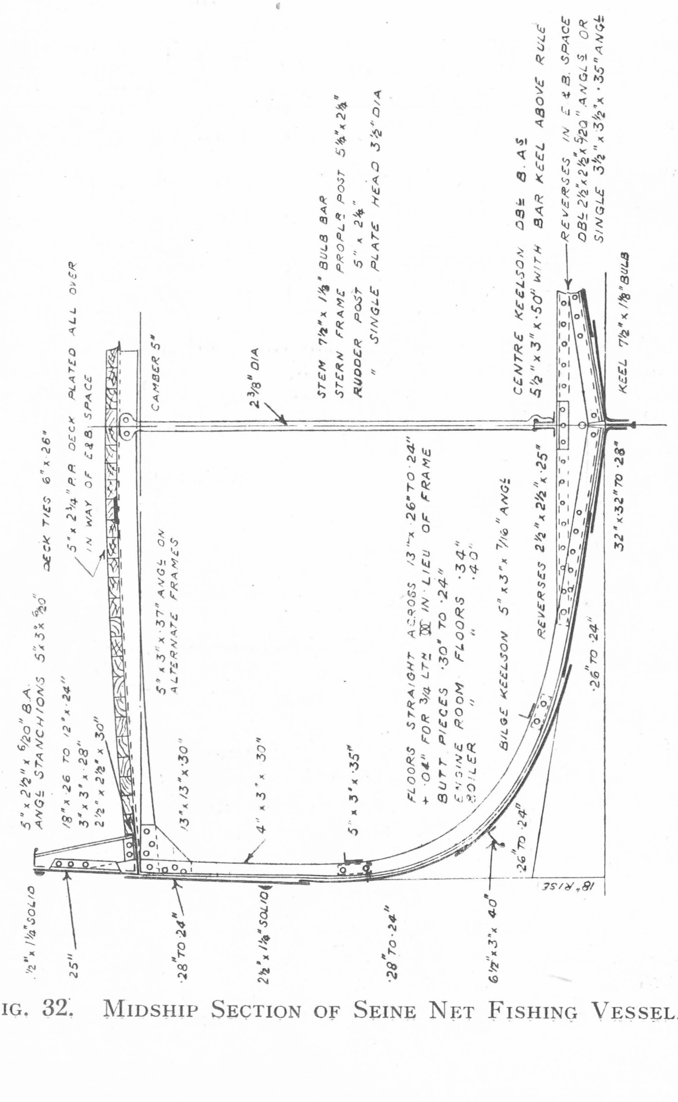


FIG. 32. MIDSHIP SECTION OF SEINE NET FISHING VESSEL.

The scantlings of the vessel, which are shown on the midship section, Fig. 32, more than comply with the requirements of Lloyd's Register of Shipping for that Society's 100 A.1 class. The keel is of the bar type, formed by a $7\frac{1}{2}$ in. by $1\frac{1}{8}$ in. bulb bar, and the same section has been adopted for the stem. The bilge keels are formed of bulb angles $6\frac{1}{2}$ in. deep. Ordinary floors are fitted throughout, there being no double bottom.

The centre keelson is arranged above the top of the floors, and is formed by double angles. An angle bar bilge keelson is fitted on each side. The side frames are of ordinary angle section, and extend from the centre line to the upper deck. The deck beams are fitted on alternate frames. The upper deck is formed of 5 in. by $2\frac{3}{4}$ in. pitch pine in conjunction with steel stringer and tie plates only, except in way of machinery space, where the deck is plated over. A steel bulwark is fitted right round the upper deck.

The equipment of anchors, cables and warps includes :—

2 Bower anchors (stockless), $4\frac{1}{2}$ cwt. each.
1 Kedge anchor (ex. stock), 2 cwt.
60 fathoms stud link cable, 13/16 in.
60 fathoms hemp hawser, $5\frac{1}{2}$ in.
60 fathoms hemp warp, 3 in.

The propelling machinery consists of a set of compound-expansion engines having cylinders 12 and 24 in. in diameter with a stroke of 16 in. Steam is supplied by a single-ended cylindrical boiler 9 ft. 6 in. in diameter by 9 ft. long, and designed for a working pressure of 140 lb.

Chapter 5.

RIVER AND CANAL BARGES.

It was probably about the latter part of the seventeenth and the beginning of the eighteenth centuries when vessels were built exclusively for inland water transport, and it was not until 1850 when machinery was installed, that barges became self-propelling units. These vessels were not generally built to any proper design, boat-builders relying solely upon their knowledge and experience of the river and canal conditions in their vicinity. They were built of wood, of lengths varying between forty and eighty feet, and were for the most part square, or almost so, in section for about four-fifths of their length. The shaping of the short, stumpy forward and after bodies was accomplished by the simple method of stopping the garboard strake at about four feet six inches from

the stem, and about five feet from the stern, and giving the butting strake at each end a complete natural twist to make it fay against the stem and stern post. The remaining strakes, being sufficiently tapered, simply followed the curve given by the garboard strake, the whole of the outside being afterwards faired by the skilful use of the adze. The shape of the forward and after bodies thus produced was of a stereotyped style, and was used without alteration for any length of boat. This method of barge building is still employed in many parts of the south of England.

In 1895, a large firm of barge owners turned their attention to the oil-engine, but the experiment of installing a motor in one of their barges did not prove a success, probably because they used the high speed petrol-paraffin engine, a type which would be highly inefficient in a vessel such as a heavy barge. The success attending the installation of a Hot-bulb (Semi-diesel) oil engine in 1909, rather stimulated the advance of this type of engine for barge work, and the British Government, during the late war, realising the value of the heavy-oil engine, installed several hundreds of barges and lighters with them, for service on rivers and canals both at home and abroad.

For convenience, Navigable Inland Waterways are classed under three headings, as follows :—

(1) Natural Channels, those rivers and estuaries which have not been interfered with by artificial works.

(2) Navigations, sometimes known as Canalised Rivers, and the flow of which, is more or less under artificial control.

(3) Canals, those waterways which are purely artificial.

The narrowness and shallowness, together with other natural difficulties, such as rises and falls, currents, etc., of the Waterways of Great Britain, Ireland, and the Continent, restrict the dimensions and proportions of barges, and owners find that they are compelled to build to suit local conditions and requirements. They have found, too, that it is inadvisable to build vessels of very large tonnage, except where they are working exclusively at the mouths of wide rivers, and manœuvring can be accomplished with ease, but to build several vessels of smaller size, capable of working in restricted waters. A plan worked upon with success, is to build upon the "fleet principle," that is, to have one high powered tug-barge, capable of towing four or more dumb barges of say, one hundred to five hundred tons deadweight carrying capacity each. Besides difficulty in locking, especially where the length of the lock necessitates the dismantling of the tow, the power absorbed in towing is greater than if the equivalent deadweight were carried in one hull, but the counter-claims of depreciation, river and canal charges, and the gains on half loads, are sufficient to bring the several smaller boats into favour. Some firms, whose barges work exclusively on canals, further this plan by building double ended canal tugs, capable of towing up to six barges. Thus,

while the barges are being unloaded, no stand-by losses are incurred, since the tug can be continually employed.

The division of the types of Inland Water Ways is instrumental in producing the following three classes of barges :—

Type I.—River Barges, working exclusively upon wide rivers, and of 300 to 2,000 tons deadweight carrying capacity.

Type II.—River Barges, working upon restricted rivers, and of 30 to 300 tons deadweight carrying capacity.

Type III.—Canal Barges, working almost exclusively upon canals, and of 30 to 300 tons deadweight carrying capacity.

The design of barges has only comparatively recently been subjected to careful consideration by Naval Architects, but it has been found by experience that the old idea of excessively full hulls, and consequently large deadweight carrying capacity, is incongruent with strict economy. While it was quite common at one time to see barges with a block co-efficient of over .89, a co-efficient of .7 to .75 is quite sufficient for all ordinary purposes.

Professor H. Sadler carried out some very interesting experiments with regard to the resistances of lighters and barges of various forms. (See Transactions of the Society of American Naval Architects. 1916). With models of various shapes varying from vessels having the forward and after bodies square in section, and with a rake of stem and stern equal to one quarter and one eighth of the overall length, and with straight and rounded deck lines, to vessels having more or less a "Ship-shape."

In curves of resistance per ton displacement to the speed-length ratio, the vessel with the "ship-shape" for one quarter of the overall length, appears to give the best results, both for deep and shallow water. As far as resistance is concerned a boat with a rake of stem and stern of one eighth of the overall length, and with rounded sides, very closely follows the "ship-shaped" vessel, while a barge of "flat-iron" shape, that is, with a curved deck line but with vertical sides all fore and aft, appears to be particularly good in shallow water, although it appears to prove inferior when in deep water. These experiments were largely carried out by means of towing models in testing tanks, and while the results are very instructive, and perhaps give some useful data, the types of models experimented with were of shapes which are barely suitable for self-propelled barges.

Full "U" sections forward, with no flare, quickly assuming the contour of the midship section, and with a long parallel middle body, with its centre of buoyancy from .08 to .12 of the length between perpendiculars forward of amidships, are characteristic of recent barges. A fairly fine run is given to the after body, both for the sake of resistance and steering, although on the other hand, but little curvature is given to the framing so as to simplify and cheapen the construction. The following figures (Fig. 33, 34, and 35) give the sheer draught of the three types of barges.

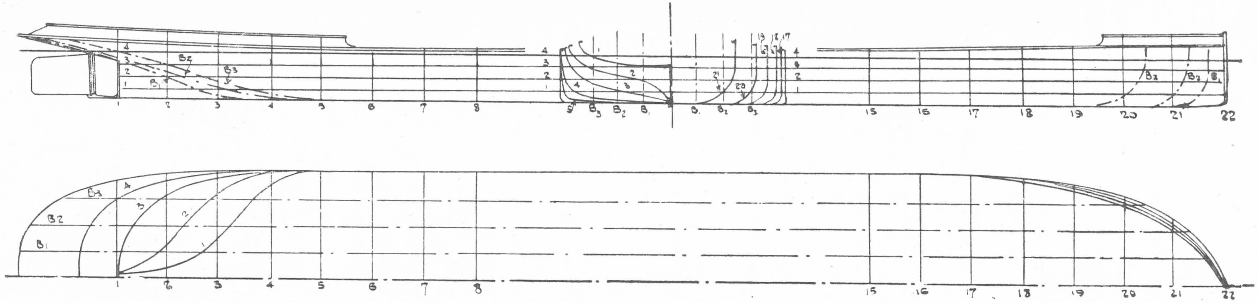


FIG. 33. SHEER DRAUGHT RIVER BARGE. TYPE 1.

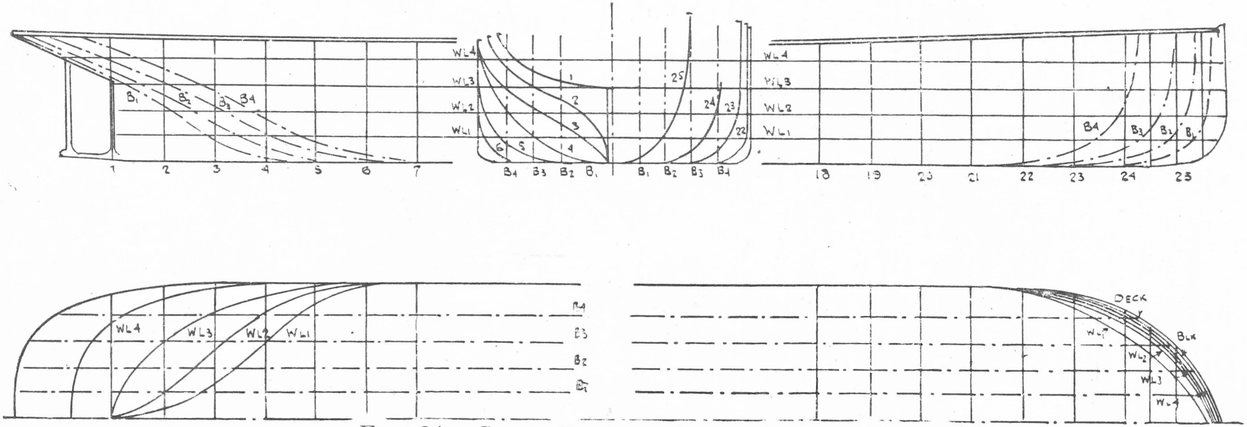


FIG. 34. SHEER DRAUGHT RIVER BARGE. TYPE 2.

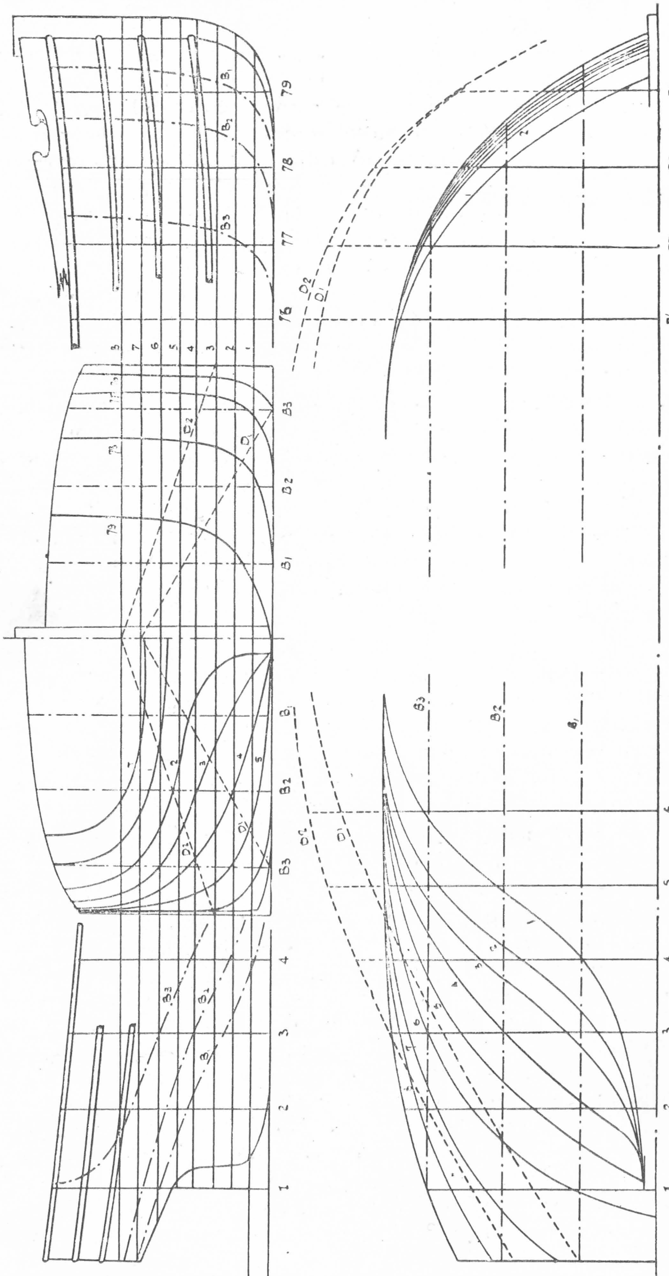


FIG. 35. SHEER DRAUGHT CANAL BARGE.

Fig. 33 gives the lines of a vessel displacing 1,500 tons which was built for service abroad. The proportions are quite normal although the forward lines are rather more full than usual. It will be noticed that the parallel middle body extends from station 5 to station 17, while the after lines show a comparatively fine run to the propeller.

Fig. 34 gives quite a normal set of lines for a barge of about 500 tons displacement. Here the parallel middle body is not so long, comparatively, as in the larger boat, and the forward and after bodies, while not being so fine as to be detrimental to the carrying capacity, are nevertheless sufficiently fine to give an economical boat. Fig 35 gives the lines of the usual 100 tons transom-sterned canal barge.

The midship section is usually very full, the co-efficient of fineness being generally between .89 and 1.00. There is little or no rise of floor, and a very small radius of bilge, and in the wooden canal barges, square, chined boats are usually to be met with. Little sheer is given as a rule, to barges of Types II. and III., although it is advisable to give sufficient to provide a dry walk fore and aft when the vessel is loaded. A fairly substantial sheer, almost similar to the smaller coasting vessels, is usually given to barges of Type I.

Stability is not an important consideration, since very little rolling is experienced in rivers and canals, but with the larger steam and motor barges working where choppy waves or swells are apt to occur, the stabilising qualities should be almost equal to those of small coasters. Usually the value of G.M. lies between 1.25 feet and 2.75 feet with a loaded vessel, although this figure is considerably exceeded by vessels of Type III.

When loaded, barges are provided with little or no freeboard, and when light the freeboard should not exceed 12 feet, and in some cases of river and canal work where very low bridges are met with, the height of any erection above the water level must not exceed 8 feet. On the French, and most of the Belgian canals, the minimum height under bridges is 3.25 metres (10.65 feet), whilst the maximum draught allowed for vessels is 1.60 metres (5.25 feet). Some of our canals, mostly in the Midlands and in the South, have been instrumental in producing, owing to their extreme narrowness and shallowness, a particular type of barge. These vessels, known as "Monkey Barges," are very long, sometimes over 80 feet, but have very small breadth and depth. The proportions of length to breadth, and length to depth, are generally about 1 :10 and 1 :13 respectively. They usually contain one large hold, about 80 to 85 per cent. of the overall length of the boat, a very small cabin built over the engine (when the latter is installed), and a chain locker and store, combined, forward. It is only within recent years that engines have been installed, and these are of the Hot-bulb type.

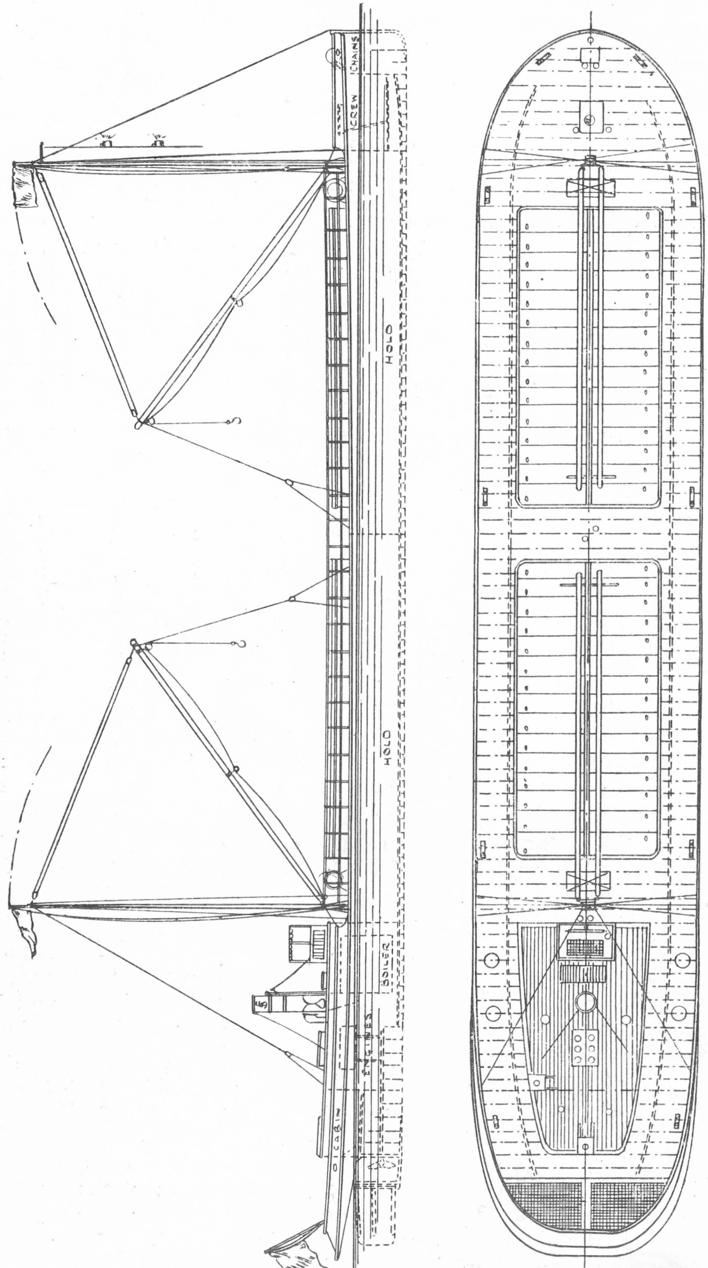


FIG. 36. GENERAL ARRANGEMENT STEAM BARGE. TYPE 1.

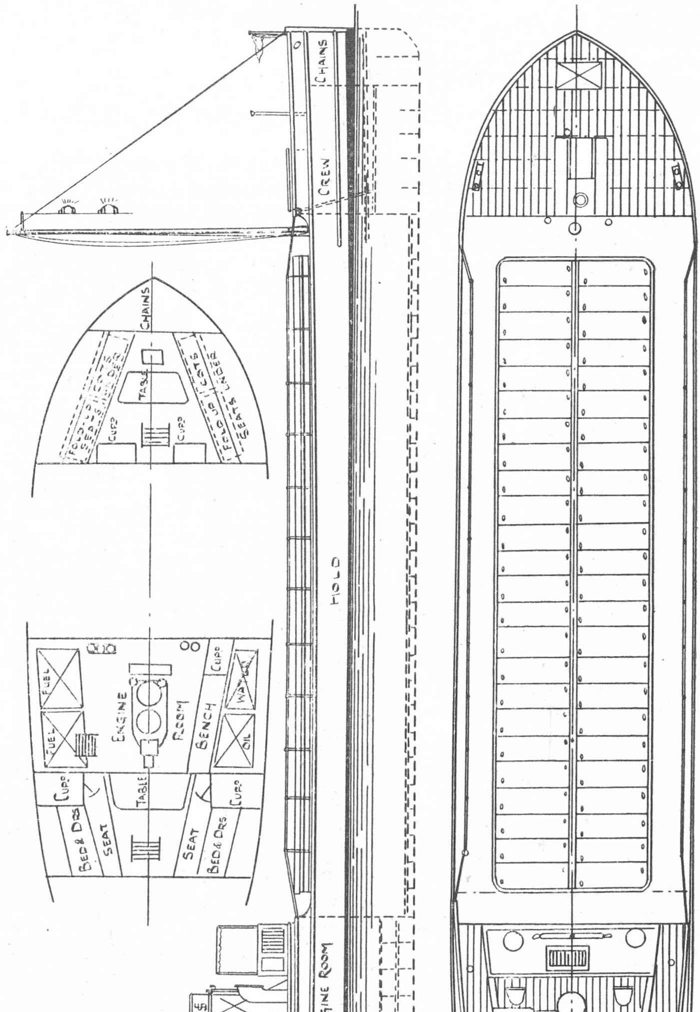


FIG. 37. GENERAL ARRANGEMENT MOTOR BARGE. TYPE 2.

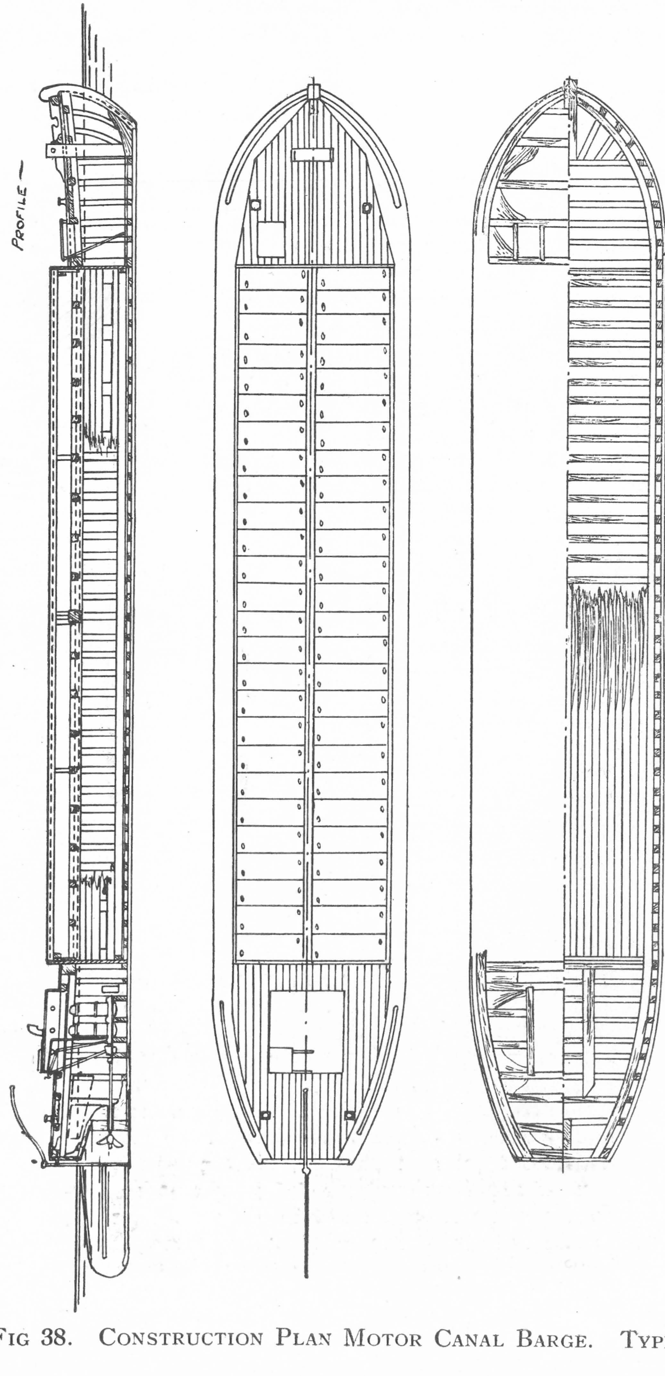


FIG 38. CONSTRUCTION PLAN MOTOR CANAL BARGE. TYPE 3.

The arrangement of steam and motor barges is of a very simple character, as will be seen by the following plans :—

Fig. 36. At the after end of two large holds are situated the Boiler space and the Engine Room. Side bunkers are shown, but where it is necessary to carry a large quantity of coal a transverse bunker is provided at the forward end of the Boiler Space. At the after end of the Engine Room are situated the Captain's and Engineer's quarters. At the forward end of the Boiler Casing a small steering bridge is fitted. The Crew are accommodated forward, just abaft the chain locker. The deck equipment consists of a steam windlass forward and two steam winches for working the cargo.

Fig. 37 gives the general arrangement of a somewhat smaller vessel, and a type which has gained popularity on the Thames. The crew are quartered forward, and the Captain and Engineer, aft. The Motor Room is at the after end of the hold and there is one large Hatch. It will be noticed that towing equipment is provided, this type of vessel being particularly adapted to work under the "Fleet Principle" in the somewhat less restricted waters.

Fig. 38 is the arrangement and construction plan of the "London Pride," a 100 ton canal barge which was recently built for service on the Grand Junction Canal. A 20 B.H.P. oil engine is fitted well aft, a small space is allowed for the crew forward and the remainder of the length is taken up by the hold.

The "Dortmund," an 825 tons deadweight barge, is one of the largest vessels of her type fitted with internal combustion engines. Her machinery consists of two 28 B.H.P. Kromhout Engines, driving twin screws, which give a speed of 4.1 knots. An illustration of this vessel is given by the courtesy of Messrs. Perman & Co., Ltd., of London, who have had considerable experience with this class of vessel.

The "Wild Swan," another of their boats, is a good example of a vessel which comes under Type II. Capable of carrying 100

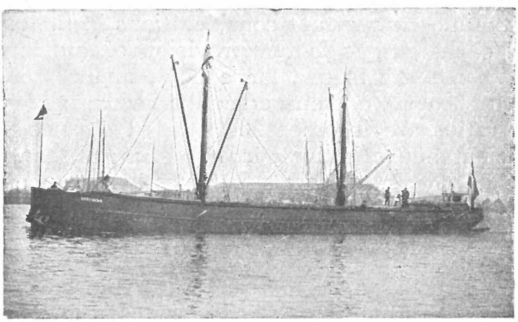


FIG. 39. "DORTMUND."

tons, this vessel is fitted with 90 B.H.P. Kromhout Engines which give her a speed of about 8 knots.

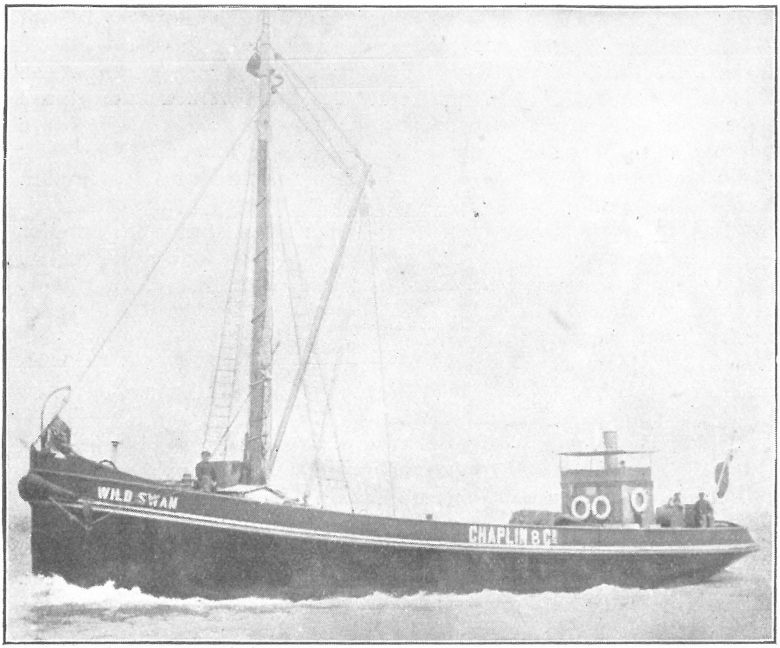


Fig. 40. "Wild Swan."

In Figs. 41, 42, and 43, curves are given for the approximate determination of the dimensions, etc., of the three types of barges. These curves, it must be remembered, are subject to local conditions and requirements.

One of the most important considerations in the construction of river and canal barges is the provision of ample transverse strength. When there is one large hold, and there is lack of support by intermediate transverse bulkheads, and where the beam-length ratios are incompatible, it is a difficult problem to provide sufficient and effective girders. Barges, too, are often working in tidal rivers, and are sometimes loaded when aground. The tendency to transverse deformation is, therefore, comparatively great, especially where the loading berth is uneven, or of a stony nature, the weight of the cargo, together with that of the boat, tends to crush the bottom and push the sides outwards. Where the bottom is only partially supported, the conditions are even more aggravated, and the shell plating suffers great stresses,

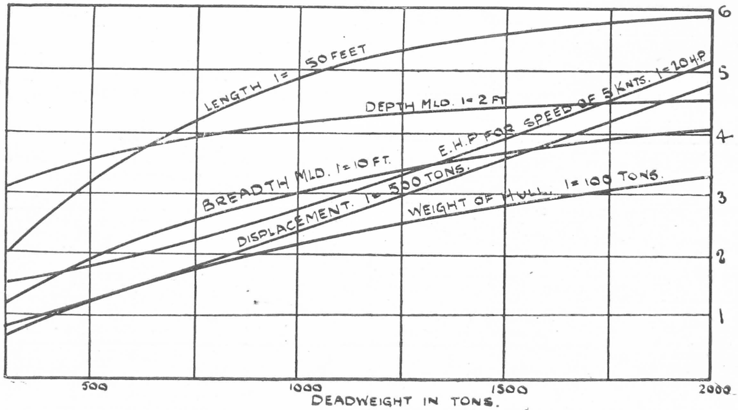


FIG. 41. CURVES OF DIMENSIONS. BARGES TYPE 1.

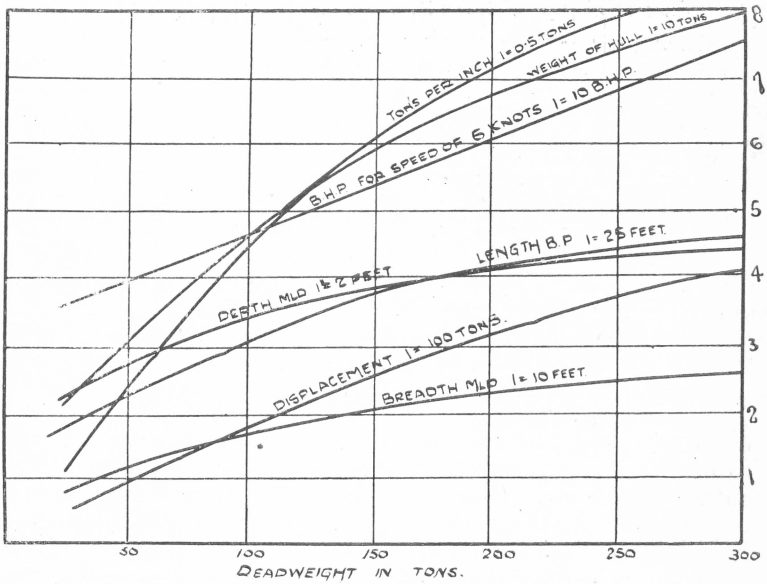


FIG. 42. CURVES OF DIMENSIONS. BARGES TYPE 2

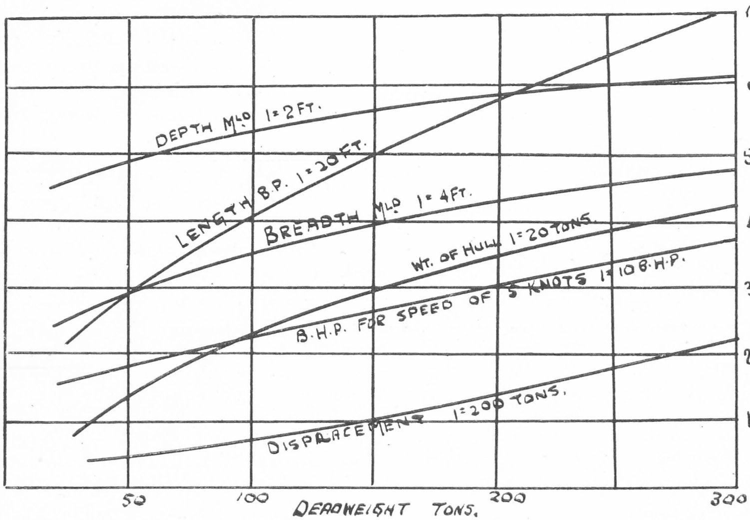


FIG. 43. CURVES OF DIMENSIONS. BARGES TYPE 3.

and tends to sag between the frame spaces. It has been known in some cases where total bending and even fracture has occurred. Severe local strains are experienced when partially or unevenly loaded with a cargo of high specific gravity, or when in light condition, and when not totally water-borne.

It is, therefore, necessary to provide ample strength of bottom, by increasing the thickness of the shell plating (this is also necessary owing to the great wear and tear) and fitting deeper floors and stouter keelsons, frames and reverse frames, together with having substantial longitudinal framing. Here, especially, will be seen the value of providing pillars for effectively binding together the top decking and the floors of the barges. Although they interfere with the cargo, insomuch that the hold space is not so clear, it is nevertheless of great importance that as many pillars as practicable should be arranged. Special care must also be taken in making efficient connection of the side framing to the floors and to the beams. One, two or three web frames are usually placed in the length of the hold in the larger vessels, at which places stout portable hatch beams are fitted. It is common in some types of canal barges, generally those of the smaller size, to fit a strong permanent beam amidships, well connected to the hatch coaming so as to provide an intermediate support. To give compensatory transverse support at the hatch ends, deep bulb-plates and angles are sometimes fitted instead of the usual bulb angle. To give good longitudinal stiffening, and also for protection, it is a common practice to double the sheerstrake. Instead

of the wooden fenders, which would be very quickly torn away, convex or half-round iron bars are used in exposed areas. In some cases a doubling plate is fitted to the keel, although it is more usual to fit one keel plate of a substantial thickness.

With larger boats of Type I., the keelsons are intercostal, and the upper keelson angles are fitted continuously, fore and aft, as far as practicable. With the smaller vessels of Type II. only keelson angles are fitted which, standing upon the tops of the floors, are continuous all fore and aft. The hold bottom is generally covered with Pitch Pine or White Pine ceiling boards, 2 to $2\frac{1}{2}$ inches thick in the larger boats, and between $1\frac{1}{2}$ to 2 inches thick in the smaller. When a barge is continually employed in carrying certain cargoes, it is usual to fit a $\frac{3}{4}$ to $1\frac{1}{2}$ in. grating. The hold sides always have battens of Pitch or White Pine boards, varying between 1 to $2\frac{1}{2}$ inches in thickness.

Figs. 44 and 45 give the midship sections of barges of Types I. and II., from which details of construction may be easily seen. In Fig. 44, it will be noticed that while there is a comparatively great breadth to depth, the frames are of somewhat light scantlings, but here the reverse frames are continued up to the heads of the frames. In some vessels the frames are made up of bulb angles, and the reverse frames stopped just above the turn of the bilge. Double angles back to back upon the stringer plate form the stringer, which extends all fore and aft. In some vessels it is usual to fit two stringers each consisting of double angles fitted back to back, upon the face of the reverse frames, or to the edge of the frames and attached to them by means of angle lugs. Fig. 45 shows a smaller vessel. Intercostal keelson plates are fitted, although it is by no means unusual to omit these and fit only continuous double angles on the tops of the floors. A centre intercostal keelson plate should, however, be used wherever practicable.

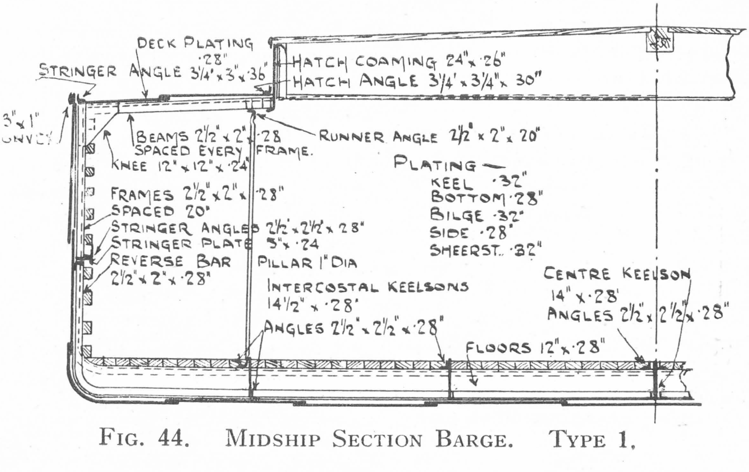


FIG. 44. MIDSHIP SECTION BARGE. TYPE 1.

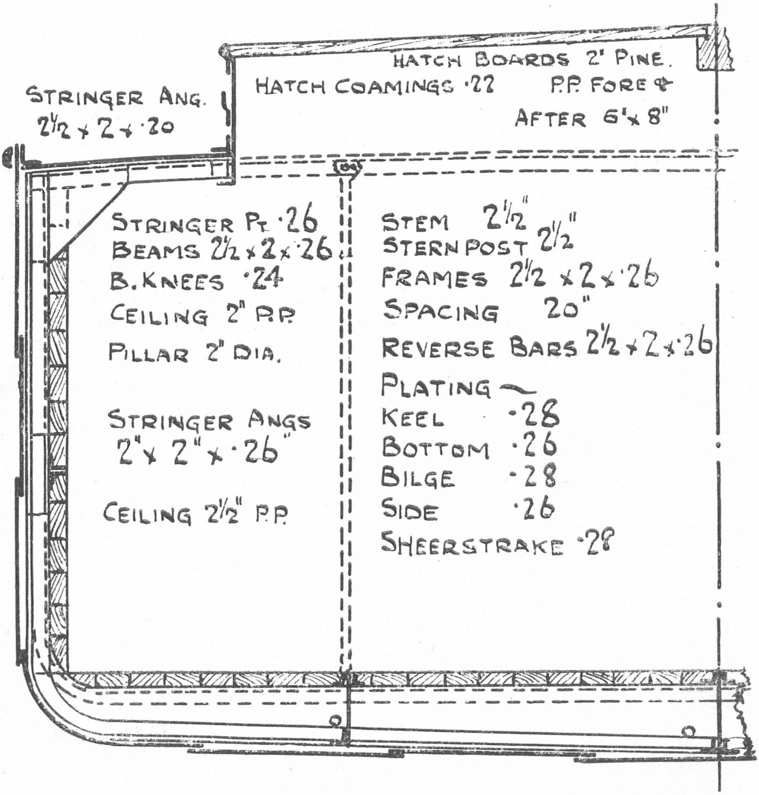


Fig. 45. Midship Section Barge. Type 2.

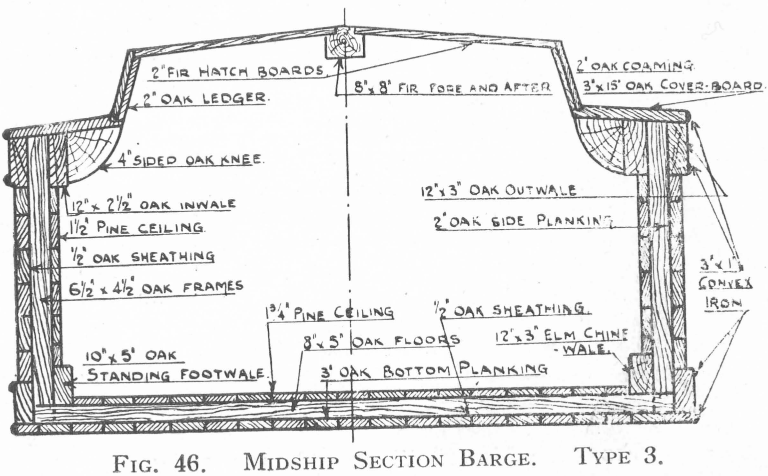


Fig. 46. Midship Section Barge. Type 3.

Although being gradually superseded by steel, the construction of wooden barges is still quite common, especially in the Southern part of England. They are generally built of hard wood although Pitch Pine and Larch are often used for planking and decking. By Fig. 46, the midship section of a 100 tons deadweight Thames barge, it will be seen that the construction is reduced to the simplest. The frames or timbers are stout oak crooks, side bolted to the floors or sleepers against which they stand. At the forward and after ends where the shaping is difficult, cant frames are employed. The bulkhead frame is made up of a stout Oak knee, through bolted with the floor against which it stands, and side bolted with a ledger piece, and the bulkhead planking, which is laid vertically, is generally of Oak from 2 to 3 inches in thickness. A stout outwale, inwale, standing footwale and chinewale, run the whole length of the boat, on each side, providing ample longitudinal strength. These wales are generally of Oak, although Elm is sometimes used for the chinewale. At the sharp bend of the bows, the outwale is generally made up of two thicknesses, which are scarphed into the solid by a four foot scarph.

Beams are not employed in the length of the hold, stout knees or chocks giving sufficient connection between the inwale and the coamings. A strong beam, however, is utilised at the half length of the hold, together with portable beams fitted at quarter lengths. Convex or half round iron rubbing strakes are fitted to the upper and lower edge of the outwale and the chinewale, and at the exposed areas of the bow and stern.

The building of barges, especially for the transport of oil in bulk, has increased very considerably within recent years, owing to the growing need of greater facilities in the speedy unloading of oil tankers, and the quick and economical transport of the oil to its destination. Where otherwise it would be necessary to pump the oil into large containers, and from thence into barrels for delivery, the barge, in many cases, can convey the oil direct to the consignees' wharf.

The nature of oil makes it necessary that certain precautions must be taken in the design of barges intended to carry oil in bulk. When carrying a free liquid cargo, whether it be oil or water, there is a danger of the vessel capsizing if insufficient stability, or insufficient transverse and longitudinal bulkheads, for checking the rolling of the cargo, are provided. Should there be a slight heel in the process of filling a vessel which has only one large hold, the liquid cargo would, of course, run to that side, thereby increasing the heeling moment very considerably. It is therefore necessary to provide ample stability, and also to provide sufficient bulkheads. Another point which needs consideration is that, while with ordinary cargo, *i.e.*, of a solid nature, the weight acts vertically downwards upon the floors,

bottom plating, etc., a liquid cargo exerts an equal pressure in every direction; thus, with the exception of the variation of pressure due to weight, the side plating receives a pressure both from the inside, due to the oil, and the outside due to the water in which the vessel floats.

The fact that the gases which arise from oils form a dangerous explosive gas when it mixes with the atmosphere, makes it necessary to fit suitable expansion hatches. For further information on this subject the reader is referred to Chapter XII., dealing with River Oil Tankers.

Besides stability and oil tightness, the general strength of the construction is of the greatest importance. The shell, bulkhead plating, and the floors should be of substantial thickness, and if anything, somewhat in excess of ordinary barges of equivalent dimensions. The provision of a longitudinal bulkhead is important in the larger oil barges, and is generally stopped at every transverse bulkhead. Sufficient transverse bulkheads, which should be oil-tight, are fitted to provide the necessary transverse stiffening, and to minimise the pressure of the oil when the vessel pitches and tosses. The transverse bulkheads should not be spaced more than 30 feet apart in barges up to about 800 to 1,000 tons deadweight capacity, and working at the mouths of large rivers or running occasional short coasting trips. With barges working under Types II. and III., the bulkheads are often 35 feet or more apart. The usual cofferdams are always two frame spaces apart. Fig. 47 gives a constructional arrangement of an oil barge which was recently built for service on the Severn. This barge measures 80 feet overall, and has a moulded breadth and depth of 21 feet and 6 feet respectively. The capacity of the hold is 5,000 cubic feet, and she could carry roughly between 125 and 130 tons of oil, on a 5 ft. 9 ins. draught. While the Captain, Engineer and Crew are all quartered forward, the Engines, which are of the Semi-Diesel type, are situated as far aft as practicable, in order to provide as large a hold as possible. The Pumping Engine, Suction and Delivery Boxes are situated in the Engine Room, together with the Fuel Tanks, etc., so that the greatest economy is made with space.

Vessels employed exclusively, or almost so, on canals often experience difficulty when locking, owing to the length of the hull and rudder. Where some of the locks measure only 75 feet between the lock gates, and a 72 feet vessel is to pass through, it is evident that when the rudder projects beyond the stern, it must be put hard over, to allow the lock gates to be closed. The fitting of hinged rudders often facilitates lock work, and Fig. 48 gives a sketch of a type which is in common use on barges working upon the Grand Junction and the Severn Canals. At the after end of the Rudder post two vertical pieces of wood are fitted, generally of Oak, which are connected together by means of a

2-inch diameter wrought iron pin which passes through four 3-inch by 1-inch flat-iron hinges, each fitted to one of the vertical members, so as to form a strong hinge. On the other side of the rudder there are two catches, or locks, which can be released from the barge by a boat hook. In locking, the rudder can be swung right over, so that the overall length of the barge is considerably reduced. Another method is to fit twin rudders, which being less in length than the single rudder, can be put hard over against the transom, without projecting beyond it. A much better arrangement is to have a rudder such as the Kitchen Reversible, and which is fully described in the chapter on Lighters. These rudders while of a short length, and, therefore, of value when locking, keep the vessel under constant control.

Hand windlasses are generally supplied to barges, since the anchors seldom exceed one cwt. in weight. In some cases, where powered winches are installed, a messenger chain is led forward to engage with the windlass.

Where barges are working on rivers where unloading appliances are absent, it is usual to fit masts and derricks for working the cargo. The masts are sometimes in tabernacles so as to allow them to be lowered when passing under bridges. Steam winches were generally fitted in larger boats, and in the bumb barges it was not uncommon to find donkey boilers at the forward end of the after cabin. Within recent years motor winches have come into prominence, motors of Horse Power varying between 5 and 10 being quite sufficient for all ordinary purposes. Several arrangements have been suggested and tried, whereby one motor can work four or more winches, and although appearing satisfactory under certain conditions, it is, nevertheless, a better plan when working with a motor winch to have a separate motor for each winch.

To prevent barges from swinging athwart a river, and thus becoming a source of danger to navigation, and to prevent undue strain upon the bow cables and anchors, barges working in rivers where strong currents are experienced, are generally equipped with bow and stern anchors, weighing between $\frac{5}{8}$ and 1 hundredweight and from $\frac{1}{4}$ to $\frac{1}{2}$ hundredweight each, respectively. Canal barges often have Rond anchors, a stockless anchor with only one fluke, for mooring alongside canal or river banks.

Although the powering of barges is not a difficult proposition, up to present but little attention has been paid to the subject. The haulage of canal barges was by means of horse or mule, which in many districts is still the standard method of towing. There have been other methods of traction introduced, however, such as by having towing locomotives ashore, or by cable haulage. Horse traction cannot be maintained at a speed greater than $3\frac{1}{2}$ miles per hour, and on some canals where there are many locks, the speed on the average is considerably less than 2 miles per hour.

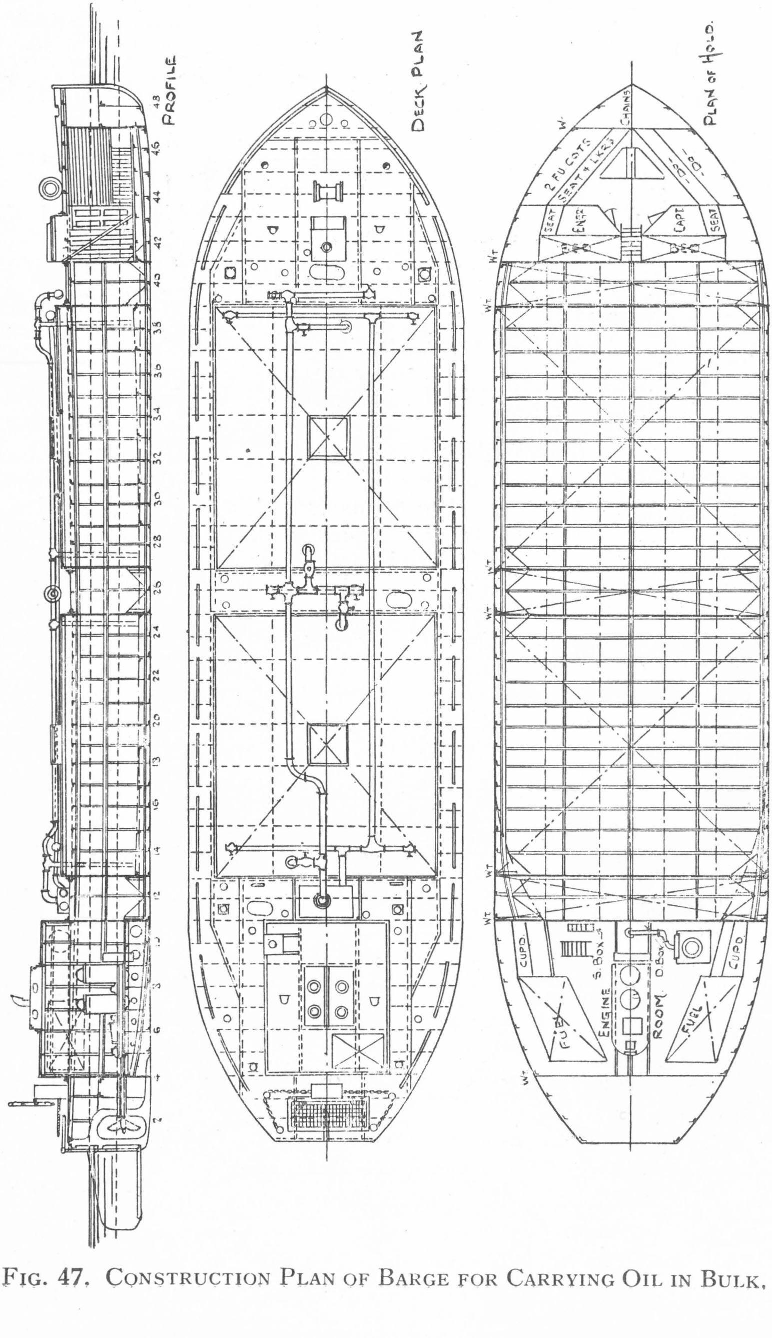


FIG. 47. CONSTRUCTION PLAN OF BARGE FOR CARRYING OIL IN BULK.

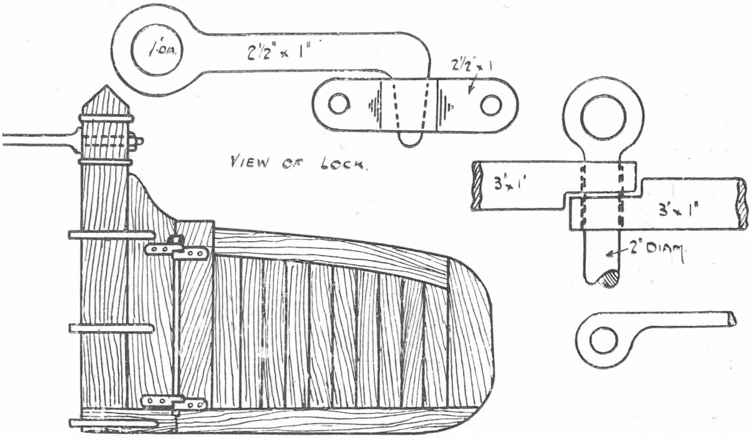


FIG. 48. ARRANGEMENT OF CANAL BARGE RUDDER.

Apart from the subject of haulage, it has been found that the wash from a vessel whose speed exceeds 3½ miles per hour, affects the banks, and renders it necessary to fit some form of protection. Although it may appear that it is inadvisable to exceed this speed when on unprotected canals, it is interesting to note that the most efficient and economical speed for a canal vessel is in terms of the propagation of the surface wave of the canal. This would be given by the formula :—

$$V = \sqrt{\frac{g\lambda}{2\pi} \tanh \frac{2\pi h}{\lambda}}$$

where h, is the depth of water from sill, in feet, and λ is the length of the surface wave, in feet. If the wave length is proportionately very great to the depth of the canal, the formula may read :—

$$V = \sqrt{gh}$$

The usual speed of canal barges lies between 3 and 5 miles per hour according to the local condition in which they work. Fig. 49 gives the speed and power curves of barges, both river and canal; these are for vessels installed with the internal combustion engines, and therefore give the B.H.P., but for curves of speed and I.H.P. the reader is referred to Chapter VII.

For the estimation of the I.H.P., many rely upon the formula,

$$\text{I.H.P.} = \frac{M \times V^3}{c}$$

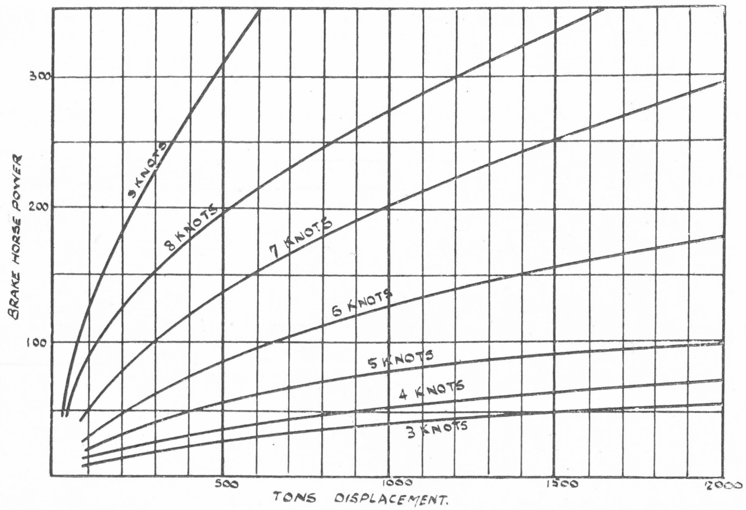


FIG. 49. SPEED AND POWER CURVES BARGES.

but this is a highly inefficient formula to use, since it is apparent that it is quite common to find barges with the same midship section but with a considerably different length, and consequently a far greater wetted surface. A more satisfactory method of estimating the I.H.P. is by the following :—

$$\text{I.H.P} = \frac{c \times S \times V^3}{100{,}000}$$

Where V = Speed of the vessel in knots.
S = Area of wetted surface, in square feet.
c = a coefficient varying between 4 for fine vessels and 6 for full vessels.

A variation of this formula is : $\text{I.H.P.} = 0.001 \sqrt{W \times L} \times V^3$

Where W = the total displacement of vessel, in tons.
L = length of vessel, B.P., in feet.
V = speed of the vessel in knots.

The design of the propeller is an important consideration, and requires special features. The usual leaf-shaped propeller does not give good results, especially when the faster marine oil engines are installed. With a slow speed boat there is always a great percentage of slip, in some canal barges reaching as high as 60 per cent. It is, therefore, necessary to give the barge propeller a fairly broad tip, with little or no set back. With the propellers driven by the motor, there is a tendency for designers to give a

large propeller diameter, and comparatively small pitch. There is, therefore, a very fine and inefficient pitch angle, and troubles arising therefrom, such as cavitation, etc., produce more or less worthless results. With steam installations trouble in this direction is not so often experienced, the conditions being more compatible. The pitch-diameter ratio generally lies between .65 and 1.00, the former, of course, being for the higher speed engines. Fig. 50 gives the diameters and pitches suitable for the higher speed motors of the hot-bulb type. These curves are only approximate, but they will be sufficient to form a guide for the determination of these dimensions. It is usual, however, for the engine makers to provide propellers suitable for their own engines. With steam, there is not so much speculation in regard to pitches and diameters. Seaton's formula $d = \sqrt[3]{\frac{I.H.P.}{x - x^2} \times \left(\frac{C}{P \times R}\right)}$ where

x = an approximation of the real slip (often taken as 0.2 of the prismatic coefficient plus the apparent slip),
P = the pitch of propeller, in feet,
R = revs. per minute of propeller,
d = the diameter of propeller in feet,
c = 450.

is a very reliable one to use for this type of vessel, since recognition is made of slip, which is of great importance.

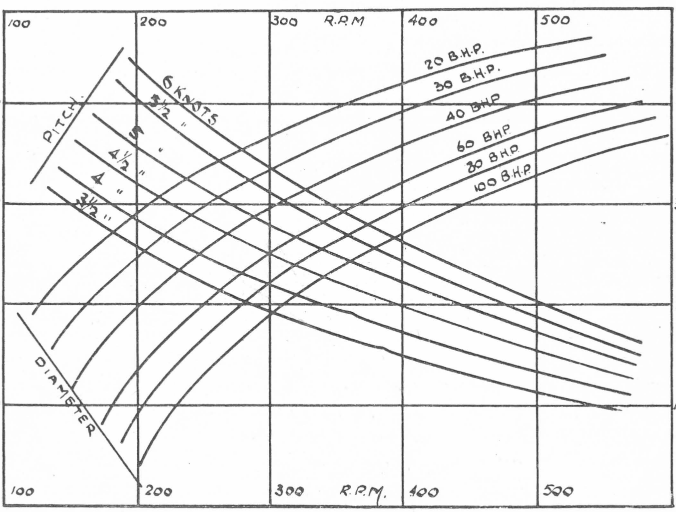


FIG. 50. CURVES OF PROPELLER DIAMETERS AND PITCHES. BARGES.

The pitch, upon which the above largely depends, is given by,

$$P = \frac{(S + s) \times 6080}{60 \times R}$$

where S is the speed of the vessel in knots,
s = the slip in knots.

In order to reduce the length of the Engine Room, it is common to instal twin-sets of machinery. Besides the advantage of gaining greater cargo-carrying space, the efficiency of the twin screws are worthy of note. The propellers having a freer run of water to their roots give results showing as much as 5 per cent. increase of efficiency over the single screws. This is particularly noticeable with the wooden barges having a very thick stern post, often over 10 inches in thickness, which prevents the water from having a clear flow into the root of the propeller.

For a discussion on the comparative values of Steam and Motor Machinery for River and Canal Barges, see Chapter XVIII.

Chapter VI.

HOPPER BARGES.

The majority of hopper barges now in use are of the dumb type and require the assistance of tugs to tow them out to sea, for the discharge of their cargo. Under these conditions a tug can tow as many as four 400 ton barges out, at one time. When dredging, there is a great advantage in the barges being self-propelling units, since they may proceed to sea, or elsewhere, independently of tugs, and to an extent, reduce the working expenses. Many dredging contractors have, say, two self-propelled hopper barges to every eight or ten dumb hopper barges, and the former being somewhat high-powered, can tow the dumb barges to the dumping ground. The advantages of this method are many, but if large quantities of material are carried in the hoppers of the dumb barges, power winches have to be installed, and donkey boilers fitted.

Dumb barges, with which we are but little concerned in this chapter, are in many respects similar to the usual river barge, with the exception that the hold is suitably divided, and the hold bottom is fitted with hinged doors. The crew accommodation is in all respects identical with the ordinary barge.

Self-propelled hopper barges can only be classified according to their capacity, and this does not materially alter the general

principles of their design. For purposes of this chapter, however, they may be classified as follows :—

Type I.—Hopper Barges working in estuaries and exposed waters.

Type II.—Hopper Barges working on restricted waters.

Under Type I., few restrictions are imposed in regard to breadth and depth, but it is nevertheless important as far as the Designers are concerned, to keep the breadth and depth of the hopper compartments within practical limits, since it must be remembered that the full weight of the cargo, etc., bears directly upon the hopper doors, which being movable, do not offer the same support as would a rigid construction. Therefore, even if there are no restrictions as far as service is concerned, owing to the ample breadth and depth of the river or estuary, limits are imposed by constructional strength considerations.

With vessels working under Type II., the narrowness and shallowness of the rivers, and canals, as the case may be, impose restrictions on both breadth and depth, so that considerations other than constructional need attention.

The design of the larger hopper barges resembles that of the larger river barges and lighters. The midship section neglecting the hopper doors, is very full, the coefficient of fineness being anything between 0.80 and 0.95. The floors are flat, and only a very small radius of bilge is given. The sides are continued vertical for a great length forward and aft. The forward sections are always of the full U type, and the flatness of bottom is preserved as far forward as possible, in order that some reasonable protection be given to the hopper doors. There is no flare to the forward sections, sufficient protection being given to the deck, if necessary, by the fitting of forecastle bulwarks. Dredging operations are usually suspended during indifferent weather, and never do hopper barges proceed to sea for discharging purposes when a heavy sea is running.

When self-propelled hopper barges, the engines are situated aft, owing to the economy of space, and the extreme impracticability of fitting a shaft tunnel in way of a hopper hold, and it is therefore necessary to provide as compatible after lines as the case will allow. The hoppers are arranged as far forward as practicable, in order that the engines may be reasonably well forward to give a somewhat fine after run. When the after body is unduly full, the resistances and inefficiency of propulsion result in an undue loss of power. In turning to Fig. 51 the sheer draught of a hopper barge working under Type I., it will be seen that the parallel middle body merges into the after body, practically at the after end of hopper No. 4, and after a small curve which extends to the middle of the engine room a large sweep is given, into the stern frame, the lower waterlines showing a decided hollow. The block coefficients of these vessels should not be unduly high. If

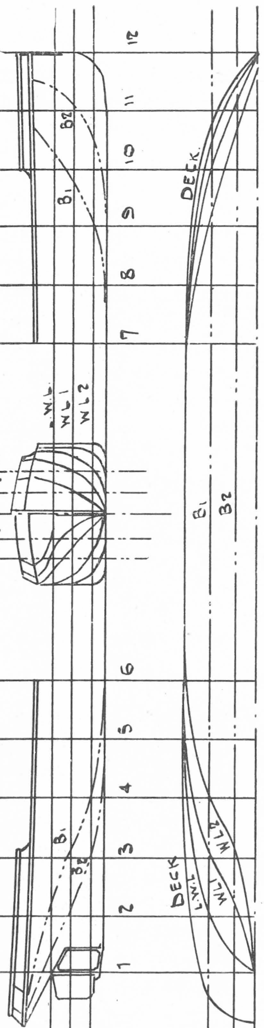


FIG. 51. SHEER DRAUGHT HOPPER BARGE.

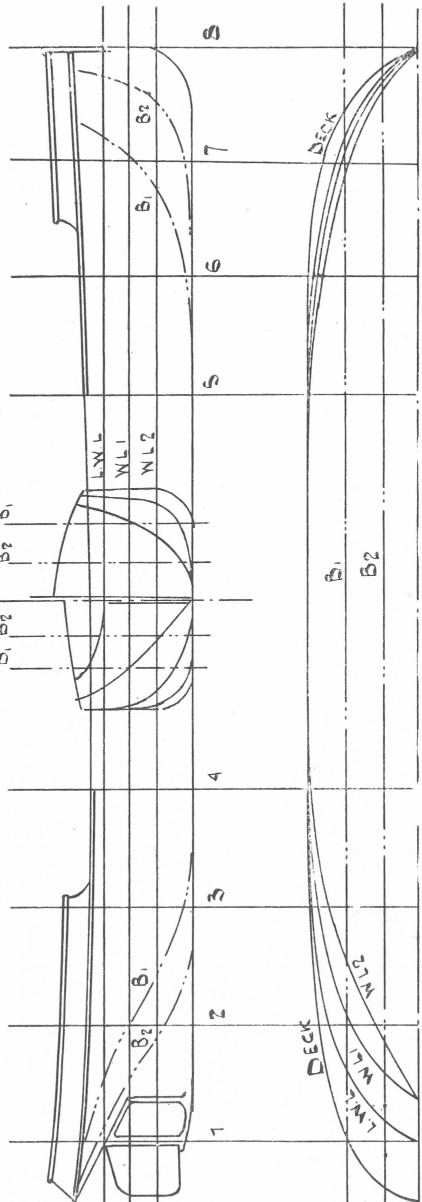


FIG. 52. SHEER DRAUGHT HOPPER BARGE.

they are kept between 0.68 and 0.78, including the loss of buoyancy due to the raised doors, the best results may be expected. Many of the large hopper barges of the dumb type have exceptionally high values for the block coefficient, one example to note giving a value of 0.93, but this is altogether unsuitable for economical working.

The hull of the smaller hopper barge, working under Type II., is generally fuller than those previously dealt with. This will be seen in Fig. 52, which is the sheer draught of a 100 tons barge, built for service on the Severn. Here the forward and after lines are full. The U sections are preserved forward, and the after waterlines show that no hollow whatsoever has been introduced. The sections in both vessels have as little curvature as possible, on account of the cheapness of this kind of construction.

While freeboard and sheer are not of great importance with these barges, sight must not be lost of the fact that ample reserves of buoyancy must be provided, since after the discharge of the cargo the hoppers are partly filled with water. Sufficient buoyancy is made by the compartments, at each side of the hoppers, and that these provide a reserve of at least 50 per cent. should be ensured by calculation.

When the hopper doors are fitted high (see later), and cargo of high specific gravity is carried, the centre of gravity is brought comparatively high. Care must be taken, therefore, to make certain that sufficient stability, and a sufficient metacentric height are given. The general shape of the under water body brings the centre of buoyancy relatively low, and if care is not taken, the boat, on the other hand, may be abnormally stiff, which if working in choppy water, may cause a dangerous shift of cargo.

Fig. 53 gives the general arrangement of a steam hopper barge. Forward are the chain locker and crew accommodation. Beneath the forecastle sole beams is a space reserved for stores, etc. The hoppers occupy the amidship portion of the vessel, and the machinery is aft. The engines are of the triple expansion type, surface condensing with cylinders 16″, 26″, and 43″ diameter, by 27″ stroke. These develop 830 I.H.P. at 115 R.P.M., and give a speed of 10 knots. The principal dimensions of the vessel are :—

Length, between perpendiculars ...	195′	0″
Breadth, moulded	29′	6″
Depth, moulded	14′	3″
Draught, maximum, aft	10′	0″
Capacity, tons	800	

The capacity of the larger hopper barges is generally between 500 and 1,500 cubic yards, say 600 and 2,000 tons, and curves are given in Fig. 54 for the determination of the principal dimensions, etc., of these craft. Fig. 55 gives curves suitable for vessels between 100 and 600 tons capacity.

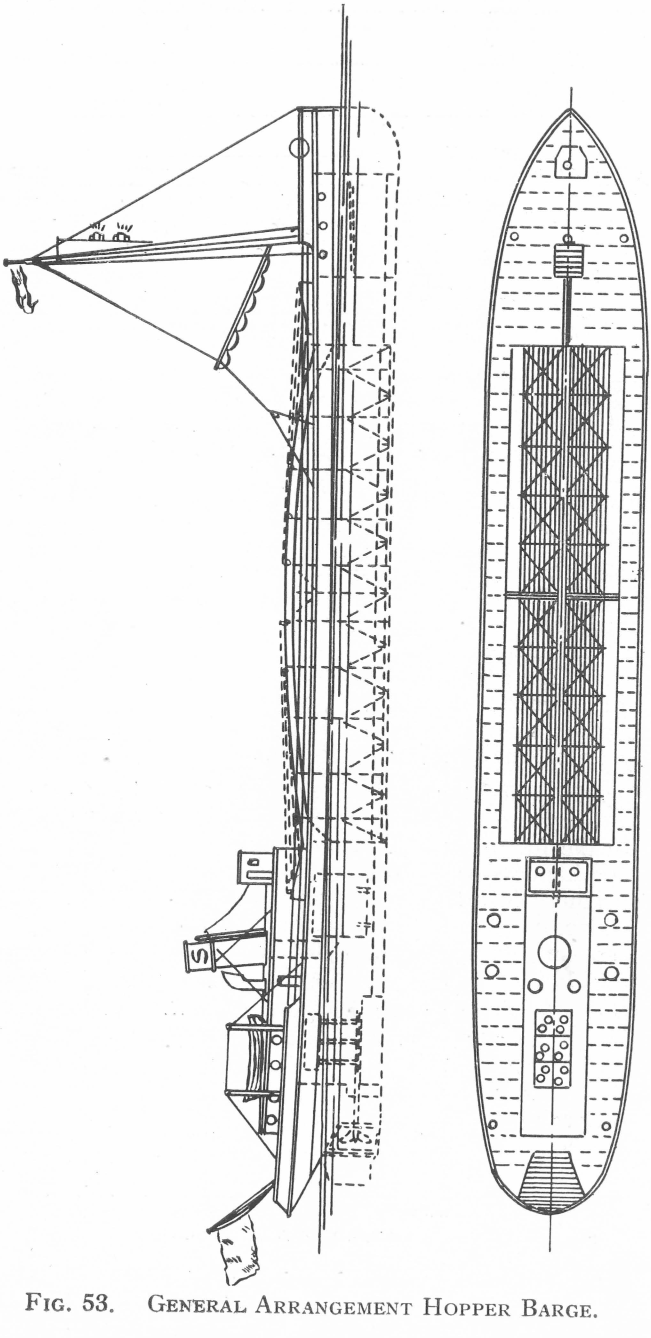


FIG. 53. GENERAL ARRANGEMENT HOPPER BARGE.

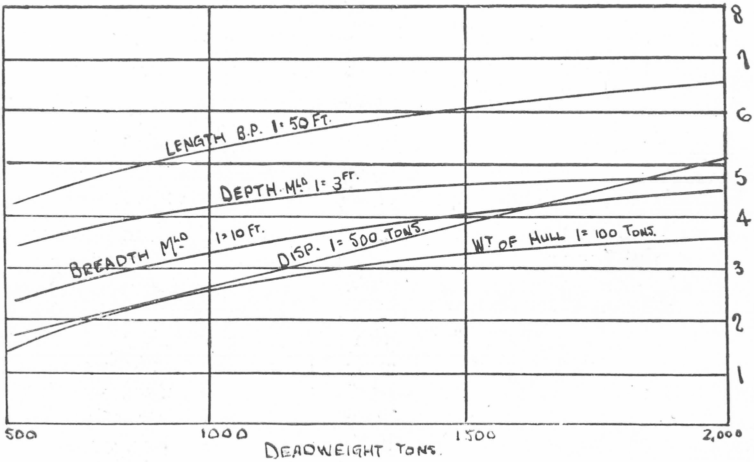


FIG. 54. CURVES OF DIMENSIONS, ETC., HOPPER BARGES.

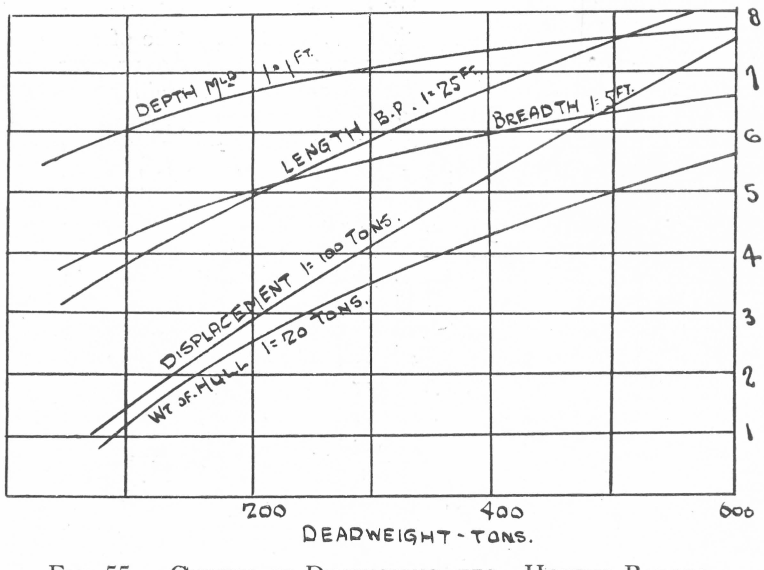


FIG. 55. CURVES OF DIMENSIONS, ETC., HOPPER BARGES.

Fig. 56 gives the general arrangement of a small hopper barge, fitted with oil engines. Her principal dimensions are :—

Length, between perpendiculars ...	100′ 0″
Breadth, moulded	20′ 0″
Depth, moulded	8′ 3″
Draught, maximum, aft	7′ 3″
Engines, Semi-Diesel type	120 B.H.P.
Speed, loaded	8.5 knots.

There are no special requirements in the design and construction of the forward and after compartments of hopper barges, since the usual systems of framing, etc., are employed. It is, however, necessary, owing to the peculiar use to which the vessels are put, to have throughout the whole vessel all the various members of substantial scantlings. The framing and longitudinal girdering must be sufficient to withstand all stresses which the vessel may have to encounter. The part of the construction which needs special consideration is the hoppers. Each hopper consists essentially of a rectangular box, the sides of which are steeply inclined or vertical. The size of each hopper depends upon the length, upon the amount of cargo, or material that is to be carried, and upon its specific gravity. In small vessels there is no need to fit transverse bulkheads in the length of the hopper, but with larger vessels, in order to provide sufficient strength, one or more transverse bulkheads must be interposed in the length of the hold. The number of bulkheads, of course, depends upon the nature of the material carried, but longitudinal bulkheads are seldom or never fitted. Transverse girders are fitted at the bottom of the hoppers, generally between each door. They must be of sufficient strength to withstand all bending moments, and a usual safety margin is given at 4, over and above the usual bending moment, and the usual margin, this making a total safety margin of 18 to 20. The bending moment depends upon the load per foot run, and may be given as follows :—

$$L = \frac{l \times \frac{1}{2}(b + b_1) \times d \times w + D - B}{Lg.}$$

Where,

L = load per foot length of transverse girder, in lbs.

l = length of each hopper compartment, between bulkheads, in feet.

b = breadth of hopper compartment at top, in feet.

b_1 = breadth of hopper compartment, at bottom, in feet.

d = depth of hopper compartment, in feet.

w = weight of material, in lbs., per cub. ft.

D = weight of hopper doors, in each compartment, in lbs.

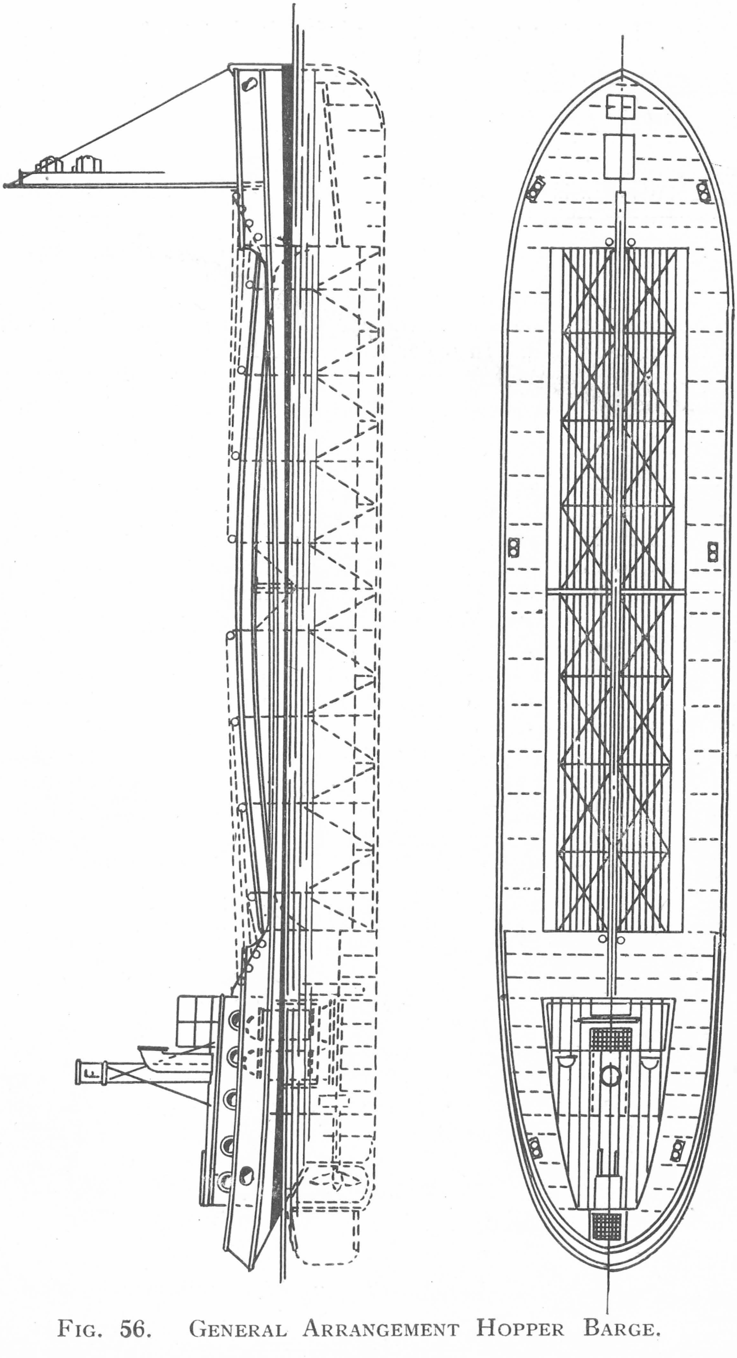


FIG. 56. GENERAL ARRANGEMENT HOPPER BARGE.

Lg = length of transverse girder, in feet.
B = the buoyancy of water in lbs., and is equal to the upward pressure of water to the under part of the hopper compartment.

Or in other words, load per foot run

$$= \frac{\text{weight of material in compartment} + \text{weight of doors} - \text{buoyancy of water}}{\text{Length of transverse girder}}$$

The transverse girders and bulkheads assist very materially in the transverse strength of the vessel, and should be well connected at each end. In order to provide longitudinal strength, a girder is fitted at the lower part of the hopper compartment, which should be continuous and well scarphed into the ordinary ship construction at either end. This girder, besides carrying the hopper door hinges, prevents to a large extent the transverse members coming together and buckling, since it affords support for the transverse girders.

The hopper doors, which are normally about 12ft. 6ins. by 6ft. 0ins., or 10ft. 0ins. by 4ft. 0ins., are arranged to fall outwards, and are supported by chains led to a central girder. The doors should be of sufficient thickness to withstand the pressure which they will have to support; the load per door can be calculated from the foregoing formula, if allowance is made for the number of doors in each compartment. This of course would be assuming the door to be a uniformly loaded beam supported at the ends. The doors are sheathed on the inside by oak or greenheart planking, 3 to 4 inches in thickness, but with small vessels pitch pine is generally used.

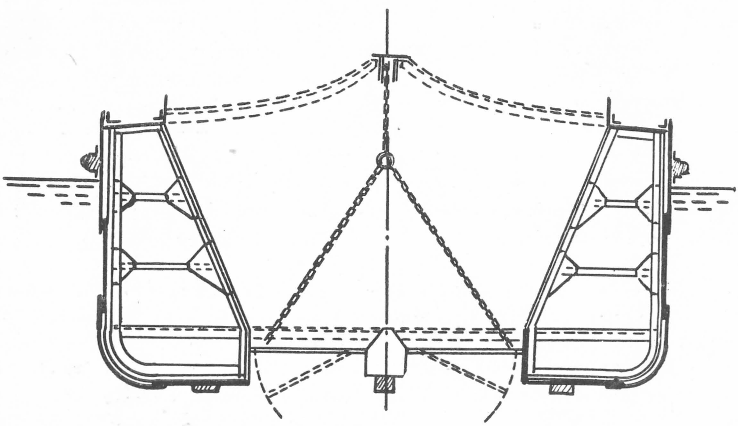


FIG. 57. MIDSHIP SECTION HOPPER BARGE.

The hopper bottom is usually recessed, see Fig. 57, about 1 to 3 feet above the line of the keel. Some doors are fitted sufficiently high in the vessels so that in light condition they are not submerged. Although the coamings are sufficiently high to give a good carrying capacity, the centre of gravity is raised vertically, and care must be taken to ensure that the stability is not impoverished. The doors are subjected to considerable wear and tear, and therefore require constant inspection. With the former this can be more or less easily accomplished, but when the doors are always submerged, a proper survey is impossible unless the vessel be put into dry dock.

The doors are actuated by chains which, attached as near as possible to the outer edge of the door, pass over sheaves and are led to the winches. With normal boats, the chain links are about $1\frac{3}{8}$ ins. thick, and the sheaves suitable for this chain would be about 20 to 24 ins. diameter. The sheaves are supported by a longitudinal girder which extends the full length of the compartments. This girder, it will be seen, supports a heavy load at a large moment, and it is therefore necessary to ensure sufficient strength, to not only build it up of exceptionally strong sections, often two bulb plates, two continuous angles and a rider plate, but to well connect it to the transverse bulkheads forward and aft. This is done by welding or fitting very deep brackets, which are connected to the girder web plates and the bulkhead plating by angle bars. The bulkheads have to be suitably stiffened on the inside, to provide some continuity of strength. A single chain is often lead over the centre sheave, and to which two other chains are shackled, each actuating the port or starboard door. The advantage of this is that the two doors can be worked simultaneously. When this is done a special centre girder has to be fitted in order to carry the sheaves, the disadvantage of this being that in the event of fracture, the sheaves are difficult to replace, and if the hopper be full dangerous results may ensue. In larger vessels a separate chain and sheave are supplied for each door, and although the doors are worked independently of each other, special arrangements must be made on the side of the girder so that they may be carried. Sometimes the chains to the doors are led alongside the hopper compartment, but the inadvisability of this plan is evident. The awkward leads of chains, the considerable extra wear and tear, together with the rub of the chain on the hopper compartment sides, fully warrants the adoption of better methods.

The compartments on each side of the hopper compartments are left empty to provide sufficient buoyancy. The inner side of each buoyancy compartment, *i.e.*, those sides which form the sides of the hopper compartments, are either vertical or are fitted at a large incline. The angle of the sides is usually between 50 and 60 degrees to the horizontal plane, the greater the tenacity of the material carried, the greater the angle; thus for soft mud, blue

clay, the larger figure is taken, whereas with stones, town refuse, etc., a smaller angle is sufficient. The plating of this side is usually arranged so that the laps face downwards, thus preventing the material from lodging on the edges, and also prevents possible damage. The framing is of the same scantling and spacing as the ordinary frames, and is attached at the top and bottom by brackets to the deck beams and the floors. To afford additional support, and as a measure against total loss should the buoyancy compartments be holed, transverse bulkheads are fitted in the compartments. The plating is generally about 1/20th ins. less than the outside shell plating, and suitably stiffened by angles, etc. Further support is given to the hopper sides by fitting stays, at suitable distances, in the buoyancy compartments. These are of angles, etc., and are attached to the frames by double plate brackets.

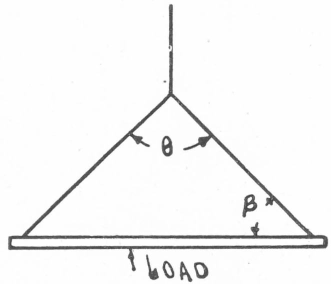
The floors throughout the buoyancy compartments are kept at reasonable depths, and the reverse frames are continued along their upper edge, and take the rivets of the lower hopper side bulkhead stiffener. The hopper coamings are between 1 ft. 0 ins. to 4 ft. 0 ins. in height, according to the depth of the hopper compartment. They are of a thick plate, continued all round the hopper compartment, the corners being rounded for strength considerations.

The coamings are attached to the deck by a foundation angle, and to afford some stiffening, a half round or convex iron bar is fitted to the upper edge. The usual hatch sections are, of course, unnecessary.

The shell plating is always of substantial thickness, and the bottom in way of the hoppers is often of the same thickness as the garboard strake that would be needed for a normal vessel of equivalent dimensions. There is little reduction in the thickness of the plating towards the ends of the vessel. Owing to the excessive wear and tear to which the sides may be subjected, the side plating must be of substantial thickness, and in many cases, the sheer strake is doubled. One or two fenders are fitted, and convex iron strips are fitted in exposed areas. The fenders are of oak, and are recessed into double angles which face each other. A convex iron facing strip is usually secured to the fender.

The deck fittings require consideration. A hand or powered windlass is placed forward. The anchors seldom exceed 15 cwts. in weight. Hawse pipes may be fitted to the larger boats, but it is more usual to fit an anchor davit, and stow the anchors on the fore deck. Light stern anchors are sometimes supplied. The most important of the deck fittings are the winches, one of which is fitted at each end of the hopper compartment. These are always of steam in the larger vessels, often over 50 I.H.P. each, where the weight of the doors is considerable, but in small vessels hand winches are arranged.

The powered winches are generally of the separate drum variety, and have catches for the chains, to relieve the weight from



SAFE WORKING LOADS FOR CHAINS, POUNDS.

Diameter, inches.					θ Degrees.				
	0	15	30	45	60	75	90	105	120
					β Degrees.				
	0	82.5	75	67.5	60	52.5	45	37.5	30
$\frac{3}{8}$ ...	700	695	675	645	605	555	495	425	350
$\frac{1}{2}$ ...	1,200	1,190	1,160	1,110	1,040	950	850	730	600
$\frac{5}{8}$ ...	1,900	1,880	1,835	1,755	1,645	1,505	1,345	1,160	950
$\frac{3}{4}$ ...	2,700	2,675	2,610	2,495	2,340	2,140	1,910	1,645	1,350
$\frac{7}{8}$ ...	3,700	3,365	3,575	3,420	3,205	2,935	2,620	2,255	1,850
1 ...	4,800	4,750	4,640	4,435	4,160	3,810	3,395	2,925	2,400
$1\frac{1}{4}$ ...	7,500	7,425	7,245	6,930	6,495	5,950	5,300	4,570	3,750
$1\frac{3}{8}$ ...	9,100	9,000	8,790	8,410	7,880	7,220	6,435	5,540	4,550
$1\frac{1}{2}$ ...	10,800	10,690	10,435	9,980	9,350	8,565	7,635	6,580	5,400
$1\frac{3}{4}$ ...	14,700	14,555	14,200	13,585	12,730	11,660	10,395	8,950	7,350

The above is given for single open-link chain. For stud links increase these values 25 per cent. The maximum allowable fibre stress has been assumed as 12,000 pounds per square inch, and the elastic limit as 24,000 pounds per square inch.

the winch. The winding drums or gipsies are as large as possible to allow an easy run for the chain. Mention has already been made of suitable chain diameters, and the following table gives the safe working loads for open-link chains. In compiling this the elastic limit has been assumed as 24,000 pounds per square inch, and the maximum fibre stress as 12,000 pounds per square inch. For stud link chain an increase of 25 per cent. can be made.

Usual fairleads, bollards, etc., are fitted for mooring, and it is not uncommon to fit a mast on the forward deck. When it is required to carry storm trysails, a fairly stout mast should be carried down to the floors. Simply a pole mast, standing in a tabernacle, is all that is needed to carry the lamps.

At the forward end of the engine and boiler room casing is usually fitted a small steering bridge. It is only with very large hopper barges that the steam steering gear becomes necessary, the smaller vessels being usually equipped with the "bridge steering gear," of suitable reduction. There are no special departures from ordinary practice in the fitting of chain leads and such items.

The speeds at which hopper barges are required to be driven depends upon their service. Several barges of this type belonging to the Port Natal Harbour Board are capable of speeds up to 11 knots. Many hopper barges employed on English rivers have a speed of only 4 to 5 knots. The power required for these vessels is totally different, and no hard and fast rules can be laid down. The powering in any case is higher than that required for normal vessels of equivalent dimensions, since, owing to the recessing of the hopper bottom and doors, the resistances are very high. The Admiralty coefficient varies between 120 and 170, according to the dimensions of the vessel. With vessels of about 1,500 tons capacity, a coefficient of 160 will give reliable results. A formula which gives good results is :—

$$\text{I.H.P.} = \frac{V^3 \sqrt{W \times L}}{1000}$$

Where,

V = Speed of vessel, in knots.
W = Displacement of vessel, in tons.
L = Length of vessel, B.P., in feet.

When oil engines are installed suitable allowances have to be made, with the above formulæ. Several recent hopper barges have been supplied with the marine oil engine, and by all reports the results obtained have been satisfactory. A fleet of motor hopper barges was recently constructed for service in India, and by the returns, statistical lists have been compiled. These show that with a vessel of 800 tons capacity, making two trips to sea, for dumping, per day, carrying full cargo each time make a saving of approximately £50 0s. 0d. per week. This is chiefly made up

by the reduction in staff, smaller cost of fuel and the total reduction of standby losses. As regards to the saving in staff, the stokers and trimmers were Hindoos, so that if the vessel were employed on an English river, a smaller saving would be effected, since black labour is considerably cheaper than white.

The propellers do not divert from regular practice to any appreciable extent. With steam the four-bladed propeller seems to be preferred, at least with the larger barges. The curves and formulæ given in the chapter dealing with river and canal barges will be found to answer satisfactorily for hopper barges. There may be, however, some little increase in the comparative blade area, but this never exceeds more than $2\frac{1}{2}$ per cent. of that given for the ordinary propeller. Care must be taken in the design of propellers driven from oil engines, and excessive pitches and diameters must be avoided. The oil engines installed never exceed 500 B.H.P. each, so that when over this power is required, twin, or even triple sets are installed. The twin sets have many advantages over the single sets, and wherever possible such should be adopted. With two propellers, obtaining a clearer run of water, the total efficiency is considerably increased, and to mention an example, with two vessels of the same total B.H.P. one single and the other twin screw, the latter had, besides 50 tons greater capacity, due to the decreased length of engine room, a speed of $10\frac{1}{2}$ knots against the single screw boat's 10 knots. This is entirely due to the greater efficiency for the propellers, for on several trials it was found that there was about 4 to 5 per cent. greater efficiency when the propeller was fitted at the side rather than in the centre line. This figure was arrived at with all due regard to reduction of diameter and pitch,

Chapter 7.

LIGHTERS.

Although at one time they could be classed as one type of craft, lighters and barges have, within recent years, developed into two distinct types. While the barge is primarily engaged on estuaries, "Navigations," and canals, the lighter is also expected to be capable of proceeding to sea on short trips. While it may be expected that the evolution of the lighter was concurrent with that of the barge, the first departure into a new class of vessel was made in 1855, when a French shipbuilding firm built a self-propelled sea-going lighter. This vessel, which was built of oak and elm, measured 115ft. 0ins. overall, and had a moulded breadth and depth of 24ft. 0ins. and 9ft. 0ins. respectively. With a loaded draught of 8ft., she was able to carry 200 tons of cargo.

While her proportions were much the same as the usual type of barge, she had several features which rendered her seaworthy; the greater freeboard and sheer and the increased height of the coamings, brought her between the barge and the small coasting vessel. This lighter was fitted with the surface condensing steam set, which was capable of propelling her at a mean speed of 7.5 knots.

For quite a considerable time lighters were double ended dumb craft, with very full bodies and with a large hold extending practically the full length of the vessel, the only accommodation being either a very small cabin in the after peak or a small house on the after deck.

The tendency within recent years has been in the installation of power so that the lighters may be rendered independent of tugs; and on account of the economy of space, etc., the crude oil engine has made great strides as being the foremost type of machinery employed with the smaller class of vessel. Steam, however, is still employed with large lighters of over 700 tons displacement.

The excessively full form of underwater body, with a parallel middle body extending over 80 per cent. of the overall length, was commonly believed to be the most economical form, owing to the greatly increased cargo carrying capacity, but it has been found by experience and experiment to be, in the long run, uneconomical. Professor J. H. Sadler, an American Naval Architect, conducted numerous experiments with various forms of hulls. These experiments consisted of towing models in different manners and at different speeds, the various resistances being carefully listed. The nine types of hulls were of the same proportions, the only differences being in the forms of the forward and after bodies, which varied between a box-shaped vessel with a swim at each end, the rake of which was equal to one quarter the overall length, to a proper ship-shaped vessel. It is significant that all the vessels tested were double ended, *i.e.*, the forward body was identical with the after body. It is unnecessary to give detailed results, sufficient is it to state that with all round work, the proper ship-shaped vessel proved to give the best results.

The most efficient under water body, as far as lighters are concerned, is, therefore, found by applying the above to the theory of forms of least resistance, and thus we find that by reducing the parallel middle body to 50 per cent. of the overall length, and having a ship-shaped entrance and a comparatively fine run aft, the most economical form is obtained. This means, therefore, that while a lighter may have a somewhat large value for the coefficient of fineness of the midship section, the block coefficient will be in no wise abnormal. The midship section coefficient may be as high as 0.98, or even 1.00, but in any case it would be unwise to have a block coefficient greater than 0.80, and with sea-going craft, in order to get a fine entrance, it may be advisable to keep the coefficient at a value of about 0.70 to 0.75.

If the service of a lighter be such that it may often be making coastal trips, it is not uncommon to introduce a little flare in the forward body sections, and since it is usual to fit bulwarks to the forecastle deck, for protection from the sea, this can be easily accomplished without undue reduction of buoyancy. With craft working on rivers, flare is absolutely unnecessary, full U sections usually being continued from the stem to the parallel middle body. As before remarked, the midship section is usually very full; little or no rise of floor is given especially where a lighter may often load or unload aground. A small radius of bilge should be given wherever possible, although in many cases it is more desirable to have a square chine at the bilge, in which case the chine is either carried forward to the stem and aft to the stern post, or else it is quickly faired into the usual sections. A chined vessel has a decided weakness, inasmuch as with an iron or steel ship the "fairing out" of the chine is difficult. There is considerable controversy upon the form of the after lines; many builders prefer to give a fine run to the propeller, while others bring the parallel middle body as far aft as possible, thus causing a short, stumpy after body with very hard and flat waterlines. As a rule as little curvature as possible is given to the sections in order to cheapen the construction, but this is no reason why the lines should not be comparatively fine. Vessels working in restricted waters having a light draught, and in many cases a small breadth, have, of necessity, very full lines both forward and aft, but where there are no restrictions imposed it is advisable to give as easy lines as possible.

Fig. 58 gives the sheer draught of a 2,000 tons lighter which was built for the South Coast. It will be noticed that the parallel middle body is placed well forward, and the entrance is, therefore, very full; the after lines are somewhat fine, although there is considerable flam at the upper part of the sections which give a good reserve of buoyancy and lifting power. A tug-boat stern is given, and the after and fore decks have bulwarks for protection; they are not fitted in the length of the main deck on account of working the cargo. A fairly substantial sheer is given at the ends although there is but little curvature in way of the holds. Fig. 59 is the sheer draught of a smaller lighter. This vessel carries 150 tons, on a 7ft. 0ins. draught. Her principal dimensions are:—

Length overall	92′ 0″
Breadth, moulded	20′ 0″
Depth, moulded	8′ 3″

With this vessel, it may be noted, there is a rather larger length-depth ratio than is usually given; on the other hand the length-breadth ratio is on the small side. These ratios primarily determine the type of lines, and thus we find both an easy entrance and run, although the middle body is comparatively long and full.

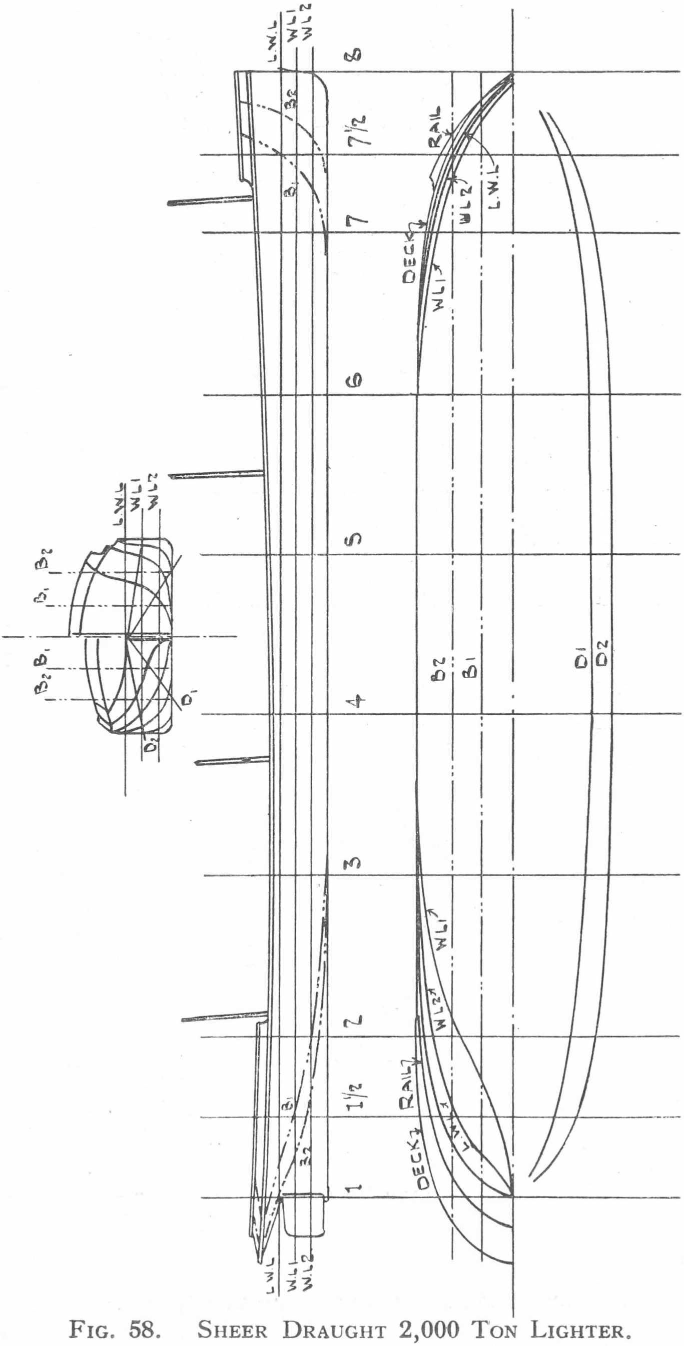


FIG. 58. SHEER DRAUGHT 2,000 TON LIGHTER.

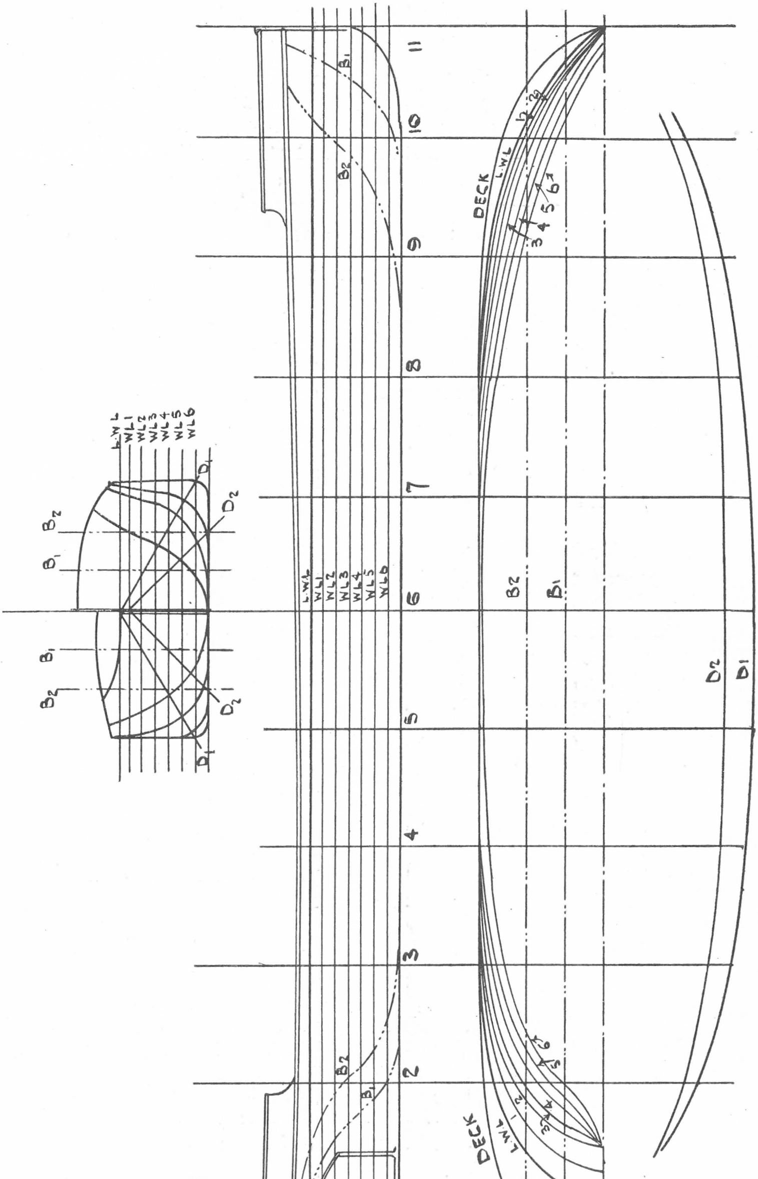


FIG. 59. SHEER DRAUGHT 150 TON LIGHTER.

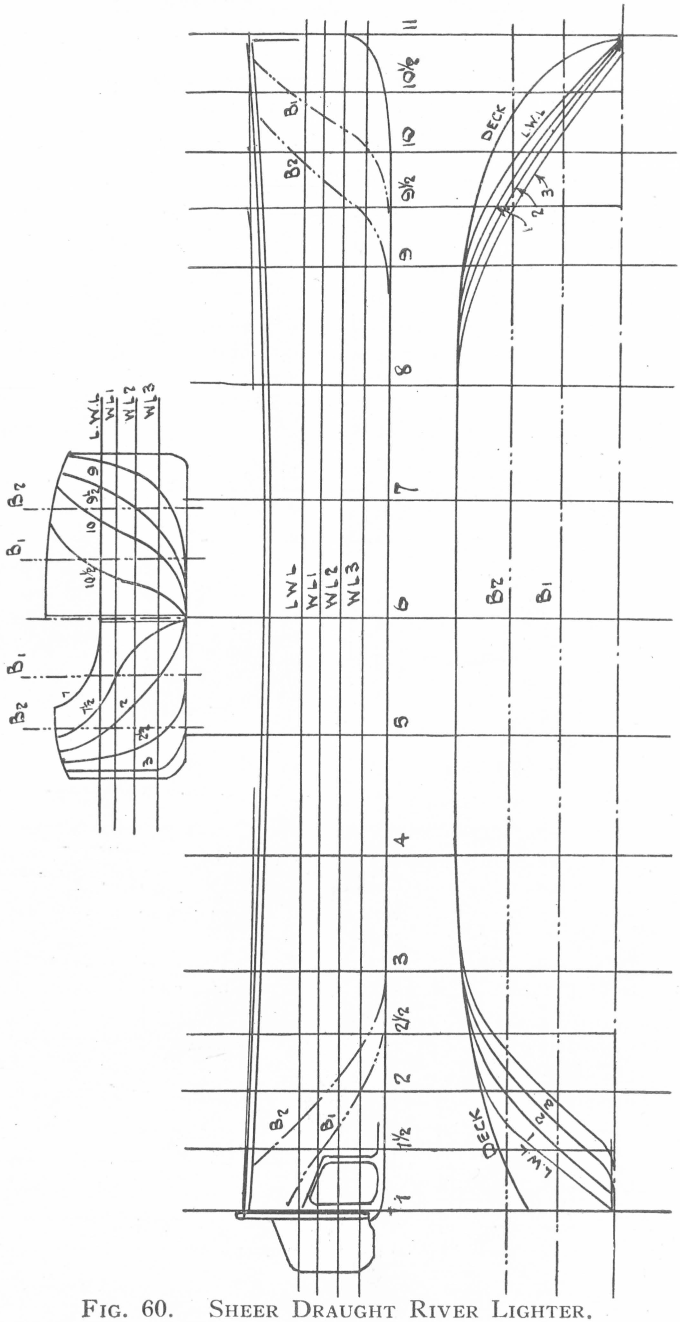


FIG. 60. SHEER DRAUGHT RIVER LIGHTER.

The ratios are great determining factors, and wherever possible it is by far the best to work upon normal proportions, and thus obtain compatible forms rather than reducing depth and increasing beam, and *vice versa*, and producing forms which are neither economical nor compatible.

When loaded, lighters have little or no freeboard when working upon estuaries and rivers, but some margin must be allowed for sea work. Usually with small lighters working on narrower rivers where low bridges have to be passed, all deck erections must be kept as low as possible, and in many cases it is necessary to have a light freeboard of only 7 feet, and many of the deck fittings, etc., may have to be portable.

The last sheer draught, Fig. 60, shows a very small river lighter, which was built for service on the Severn. Owing to bridges, the vessel has a light freeboard of only 4ft. 6ins., while the breadth of 12ft. is comparatively large. This pontoon ligher carries the full midship section to within 8ft. 0ins., of the stern post, and the after water lines, which for the most part are flat, come into the stern post at a large angle and are suitably run into the full section by a radius.

Figs. 61 and 62 give the curves for determining the principal dimensions, weights and power for lighters between 100 and 2,000 tons deadweight carrying capacity. The dimensions are subject, of course, to local conditions, but generally speaking Fig. 62 will be found to give suitable dimensions for vessels employed upon coastal and estuary work, while Fig. 61 will be found suitable for river craft. For powering and speed, see also pp. 109.

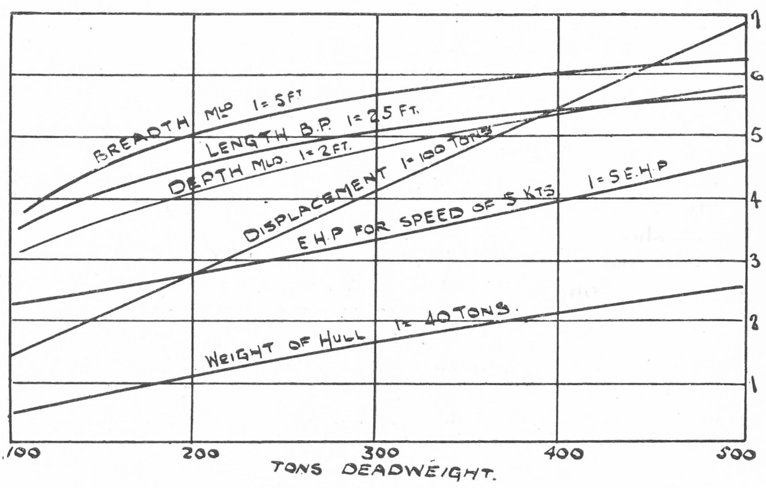


FIG. 61. CURVES OF DIMENSIONS, ETC., LIGHTERS.

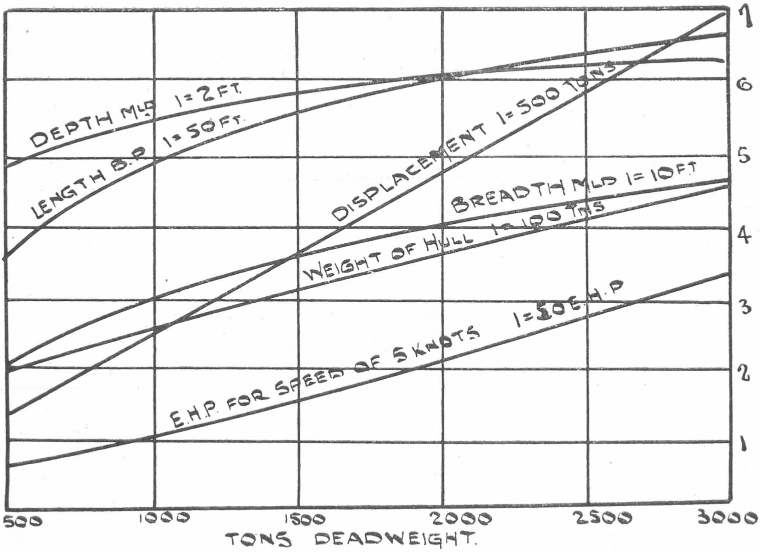


FIG. 62. CURVES OF DIMENSIONS, ETC., LIGHTERS.

Before proceeding to discuss the main features of the construction, we will consider the general arrangements of the three lighters given in Figs. 63, 64, and 65. The largest vessel, Fig. 63, has quite a usual arrangement. Her principal dimensions are:—

Length, between perpendiculars	300′ 0″
Breadth, moulded	42′ 0″
Depth, moulded	12′ 3″
Draught, maximum, aft	11′ 0″

The usual chain locker and crew space is situated well forward, while the lower part of the fore peak is utilised as a ballast tank. Three large holds, each divided by a single watertight bulkhead, occupy the greater part of the vessel, while as far aft as possible are the engine and boiler rooms. Side bunkers are fitted, but should a large quantity of coal be desired to be carried, a transverse bunker is arranged at the forward side of the forward engine room bulkhead. The Captain, Mate and Engineers are quartered in the deck houses, the after peak being used as a water ballast tank. A steering bridge is fitted at the forward end of the deck houses, the roofs of which are carried out to the side of the vessel in order that they may carry the life-boats. The deck arrangement is of a very simple character. Forward is a steam windlass, and at the foot of each mast there are one or two steam winches for working the cargo. A donkey boiler for supplying steam to the windlass and winches is situated in the boiler room in order that the winches may be worked when there is no

steam in the main boilers. The two central masts have four derricks, and the fore and after mast two; it is unusual to fit more than two masts, except where a vessel be employed on a service where the quick discharge or loading of cargo is important, and where there are no unloading appliances ashore. Other than the necessary fairleads and bollards, the decks are kept quite clear, although it may be advisable to fit stanchions along the side; if these be in the way, they can be made either portable, or made so as to fall inwards flat upon the deck.

Fig. 64 gives the arrangement of a type of lighter which has found considerable favour upon the Thames. The crew are quartered forward, directly abaft the chain locker, and at the after end of the one large hold is the engine room. The engines consist of the Semi-Diesel type of oil engine, and the fuel tanks are strapped to the side frames in the engine room, so that the greatest space possible is given to the hold. It will be noticed that the after engine room bulkhead is as far aft as possible, being only two frame spaces from the body post of the stern frame. The enclosed space may be used as a water ballast tank, since sufficient accommodation is allowed for the Captain and Engineer in the deck house which is at the after end of the engine room casing. Care must be taken when attempting to make the after deck arrangements as compact as possible that sufficient space is allowed for working; in this case it will be seen that just enough room is left abaft the house for working the vessel, although the quadrant is exposed and close to the house, some suitable grating may be arranged. The steering wheel and reduction gear is at the forward end of the engine room casing, and is simply railed off by stanchions; sometimes a wood house is fitted, in which case it is common to make the upper part portable. One large hatchway extends well forward, and neither mast nor winch is supplied; a small lamp pole stands forward of the forecastle companion. A galley and w.c. are fitted on the port and starboard sides of the forward deck, and except for a hand windlass and the usual bollards and fairleads, the deck is kept clear.

The small river lighter, Fig. 65, needs but little comment. There is no accommodation except what can be made from the very small fore peak. The engines are well aft, so that the greater part of the vessel is used as a hold. Owing to the size of the engine room, the fuel tanks are on the engine room casing, at each side, so that the view of the helmsman is not interrupted.

One of the most important considerations in the construction of lighters is the provision of ample transverse strength. The conditions are not compatible; usually there is considerable breadth with a comparatively small depth, so that racking stresses would be very severe. The continuity of the decks is always broken by the large hatchways, and the small breadth of plating between the coamings and the side of the vessel gives short

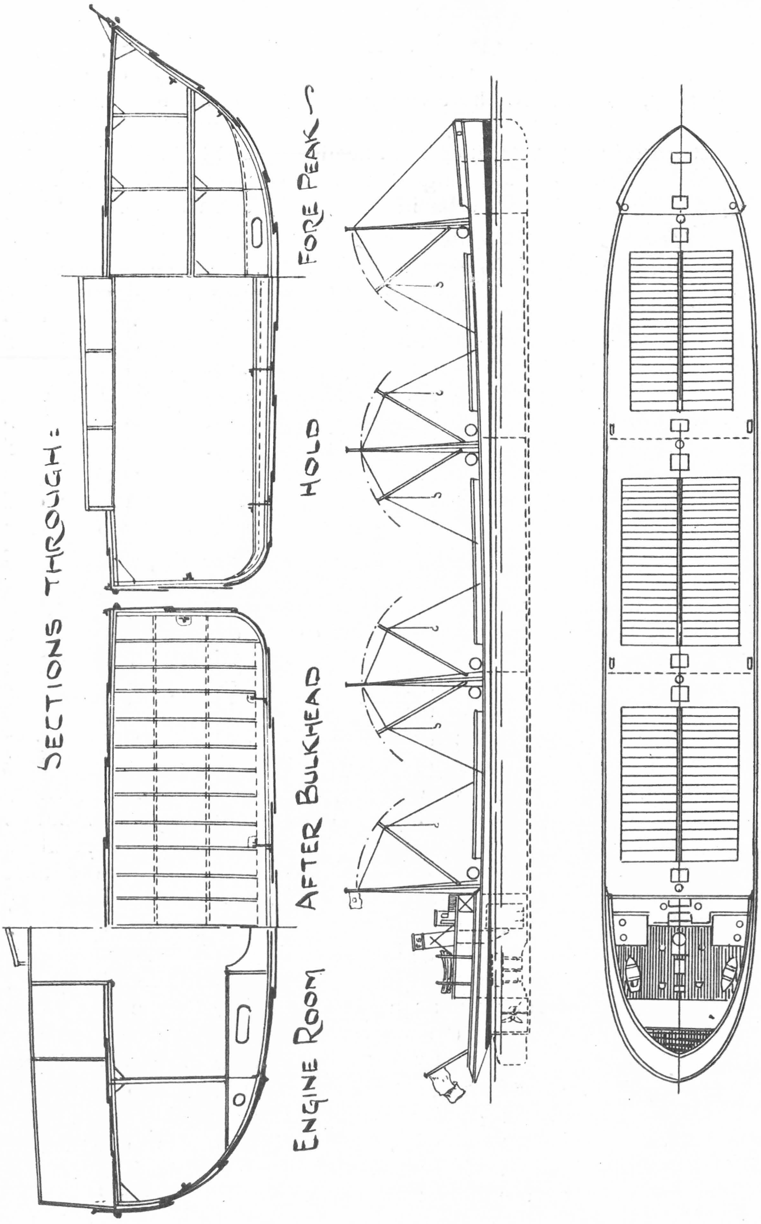


FIG. 63. GENERAL ARRANGEMENT 2,000 TON LIGHTER.

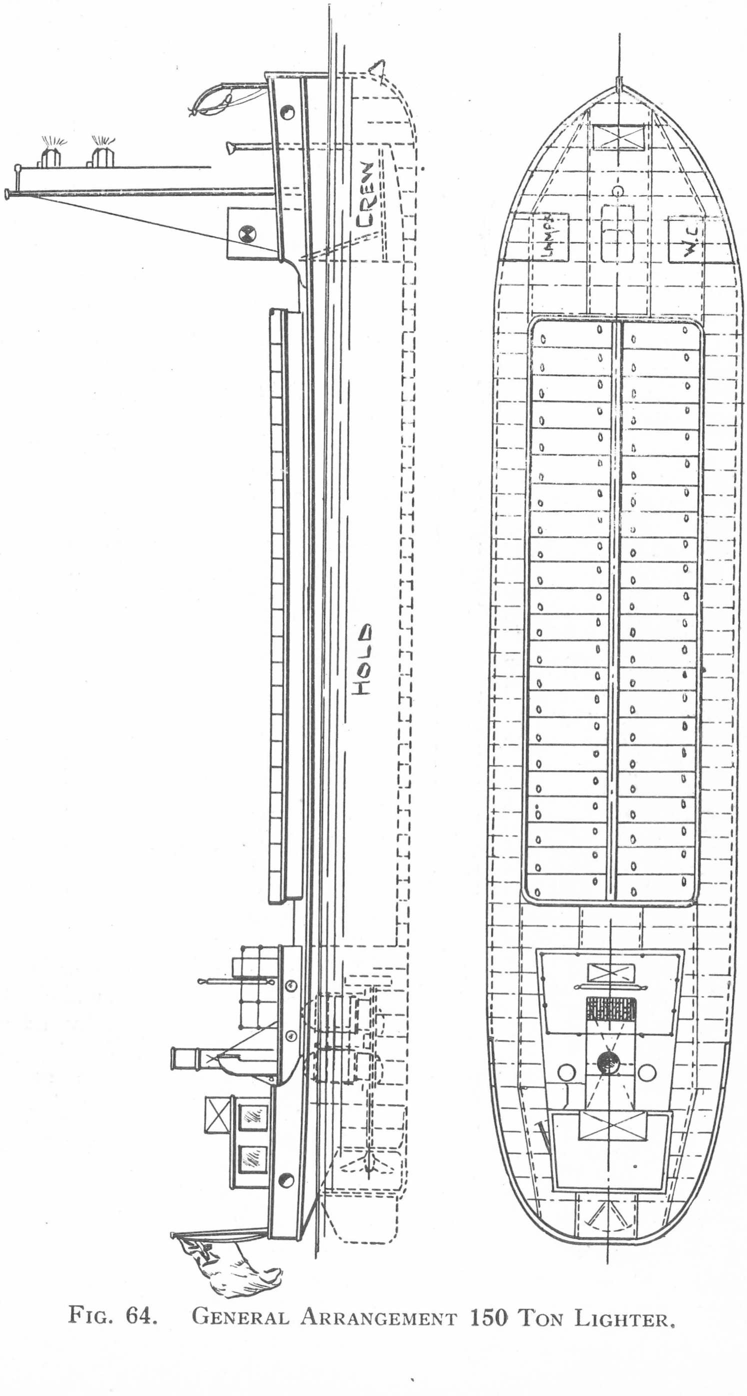


FIG. 64. GENERAL ARRANGEMENT 150 TON LIGHTER.

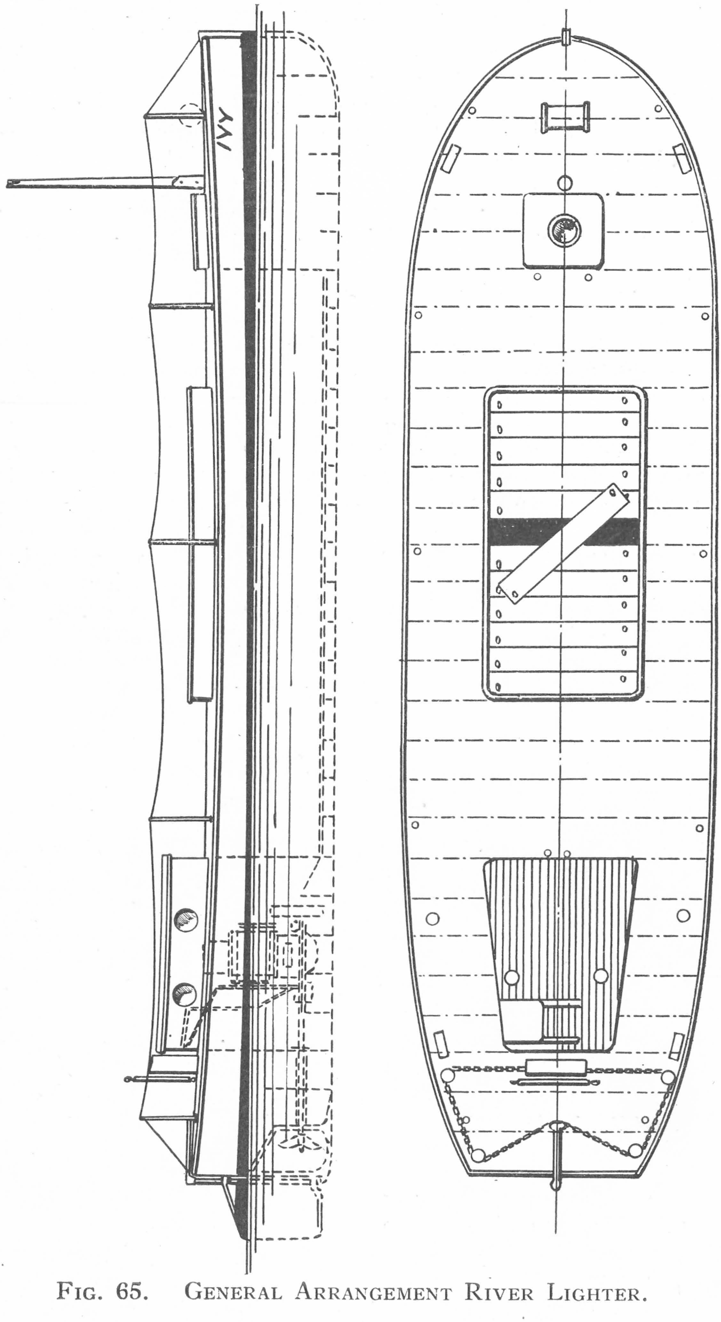


FIG. 65. GENERAL ARRANGEMENT RIVER LIGHTER.

half-beams which do not materially assist in the provision of transverse rigidity. In order that compensation may be made, it is usual to fit deep hatch coamings, and continue them down into the vessel so that they may tie well the ends of the hatch beams. Strong beams, built up of deep bulb angles, or plain angles and a bulb plate, are fitted at the end of each hatch, and it is not uncommon to fit every third or fourth half beam of heavy scantling so that in a measure some compensation is made. The chief compensation is made, however, by the efficient pillaring of the beams to the tops of the floors. The better plan is to fit a deck girder reasonably near the ends of the half beams. It may be of a single angle in small vessels, although with larger vessels double angles or even a built up girder of four angles and a plate are necessary. The pillar heads should be attached to the deck girder so that their strength and support may be distributed over as large an area as possible, and nowhere, unless it is absolutely necessary, should the pillars be fitted with portable feet, and thus only be bolted to the girder. The deck stringer plate is usually of heavy scantling, and while to a degree affording longitudinal strength, one or two side stringers, composed of double angles, are fitted along the side as far forward and aft as practicable. Finally portable hatch beams are arranged to give additional stiffening, and these should be placed opposite the heavy half beams so that greatest advantage is taken of them. The hatch beams are in one piece, the hatch fore and afters being inter-costal and fitted to the beams by double angles.

With a vessel of a small length-depth ratio, the sagging and hogging stresses it is liable to experience, exceed those of a normal proportioned vessel, and since lighters usually have a small depth, it may be expected that the longitudinal strength must be carefully considered. Besides the stresses experienced when afloat, a lighter more often than not loads and discharges her cargo when aground, or when not totally water-borne. With any unevenness of the bottom, especially if such be of a stony nature, and also especially should the vessel be partially loaded with a heavy cargo, the stresses on the bottom of the vessel are enormous, and special stiffening must be made to prevent any buckling of the shell plating. The floors of lighters are long owing to the flatness and breadth of the bottom, and it is therefore necessary to fit two or three intercostal side keelsons each side of the centre line, besides fitting an unusually strong centre keelson. The floors must be of a good depth, and often double reverse frames are fitted to provide good stiffening. All the top angles of the side keelsons must be on the tops of the floors, and continued forward and aft as far as practicable, care being taken that all the butts are well shifted clear of each other, on both sides of the vessel.

The flat plate keel is almost universal with this class of vessel, and it is not uncommon to fit a doubling strake either inside or outside the keel plate. A heavy, flat rubbing bar is generally fitted, and this should be of sufficient width to take the rivets of the lower angles of the centre keelson. The bilge plating is usually heavy, and it should be arranged that the plate which takes the curve be an outside strake, so that it may be easily removed should it in anyway get damaged. The side plating is often the same scantling as the bilge plating, this being because of the excessive wear and tear of the sides. The sheer strake is of very heavy scantling, and often doubled for at least three quarters of the overall length amidships. When there is only a single plate it should be an outside strake for reasons already given. The thickness of the outside shell plating is seldom reduced, except where the vessel be of large dimensions, or where working under compatible conditions.

Turning to Fig. 66, which gives the section of the large lighter, the foregoing remarks will be clear. It will be noticed that the bulkhead, besides having the usual vertical stiffeners, has also two transverse beams which add considerably to the transverse strength of the vessel. The deck girder or runner angles are continuous, and therefore pass through the bulkhead, suitable collars, for watertightness, being fitted, and the forward and after pillars, *i.e.*, those in the engine room and in the fore peak and crew's space, are built up of four angles which are attached to the girder by plate brackets and to the floors by bosom pieces which extend down to the floor sufficiently to take four rivets.

Fig. 67 gives the midship section of a small river lighter, and the provision of the transverse strength was accomplished in rather a novel way. Several H beams were arranged in way of the hold, but no half beams, and in their place a deep, heavy beam knee was fitted at each frame, the top edge of which was flanged to take the deck rivets. The hatch coaming was supported at every beam by plate brackets on the inside. Here a wooden fender attached to the side of the vessel by double angles is shown. It is more usual to fit half-round or convex iron bars all fore and aft, and short strips in exposed areas. These, if possible, should be placed so as to afford some protection to the landings of the shell plating, as these are very liable to be sprung and strained.

Generally pine or larch ceiling is laid upon the tops of the floors, varying in thickness between 1 inch in small vessels to 3 inches in the large. Often the ceiling is properly laid, *i.e.*, caulked and payed, but under any circumstance sufficient inspection hatches, either fitted or hinged, should be allowed, so that easy access can be made to the bilges and limber holes, etc. The sides are either lined or battened in larch or pine, secured by angle lugs fitted to the reverse frames.

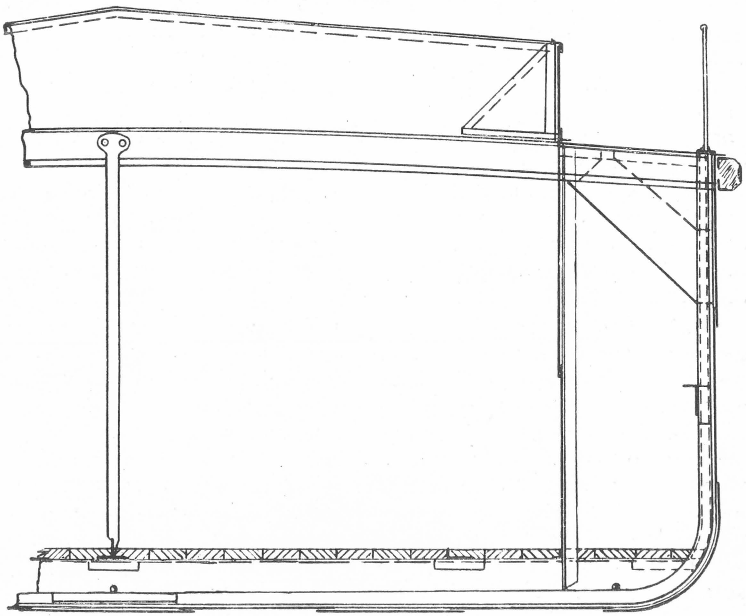


FIG. 66. MIDSHIP SECTION OF LIGHTER.

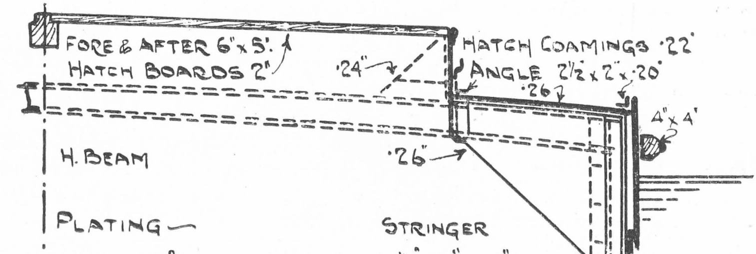


FIG. 67. MIDSHIP SECTION OF LIGHTER,

The hatch boards are generally of pine, about $2\frac{1}{2}$ inches in thickness. In some tropical lighters, instead of fitting the usual type of flat, wood hatch boards, sliding hatches are supplied. These are as a rule semi-circular, or almost so in section, and are made of steel or iron plates rolled to shape. The width of the plate varies between 3 and 6 feet, and if needs be, is stiffened on the outside by convex iron strips. One hatch covering is allowed to slide over the other, suitable grooves or rollers being arranged at the sides; they are all housed at each end of the hatch. This system cannot be recommended, the usual hatch boards and tarpaulin being far easier to work with and less liable to get out of working order.

There is considerable variation in the deck arrangements of lighters; some vessels working where there are no unloading appliances ashore, or where it is intended to unload directly into a large vessel have complete unloading appliances of their own, and on the other hand when working purely upon rivers, nothing of this is required. Short masts, either of iron, steel or wood, are, when fitted, usually on the forward end of the hatch, and two derricks, either attached by an iron gooseneck to the mast band or to a derrick table at the foot of the mast. They should be of sufficient length to serve at least half the hatchway, in small boats. The masts are wherever possible extended down to the tops of the floors, and attached to them by plate brackets, in the case of a steel mast, or into a step with a wooden mast. If the boat has to pass under low bridges, the mast must fit into a tabernacle, made up of two plates, stiffened by convex iron strips, and attached to the deck by two angles; when this is the case, the deck must be suitably stiffened, either by doubling the plating or increasing its thickness.

Sometimes small jib-cranes are placed at the side of the vessel, midway along the hatch, but these are not so satisfactory as the mast and derrick owing to their small height and consequently their small reach.

With the larger vessels, when steam sets are installed, steam winches are usually fitted, but with small boats the hand winch is generally sufficient. Motor winches are sometimes supplied to motor lighters, and apparently give satisfactory results under normal conditions. If it is intended to instal this class of winch, care should be taken in the selection of the type and make of engine. A high speed motor is of no use, for even if geared down to suitable revolutions per minute, considerable power is lost; the best type of motor is the hot-bulb, which while giving more suitable revolutions per minute, is also easy to work and control, and there are no cam shafts, valves, etc., to get out of working order. It is better to have the motor coupled directly with the winch, and although experiments have been tried whereby the winches can be driven from the main engines, by means of shafting and

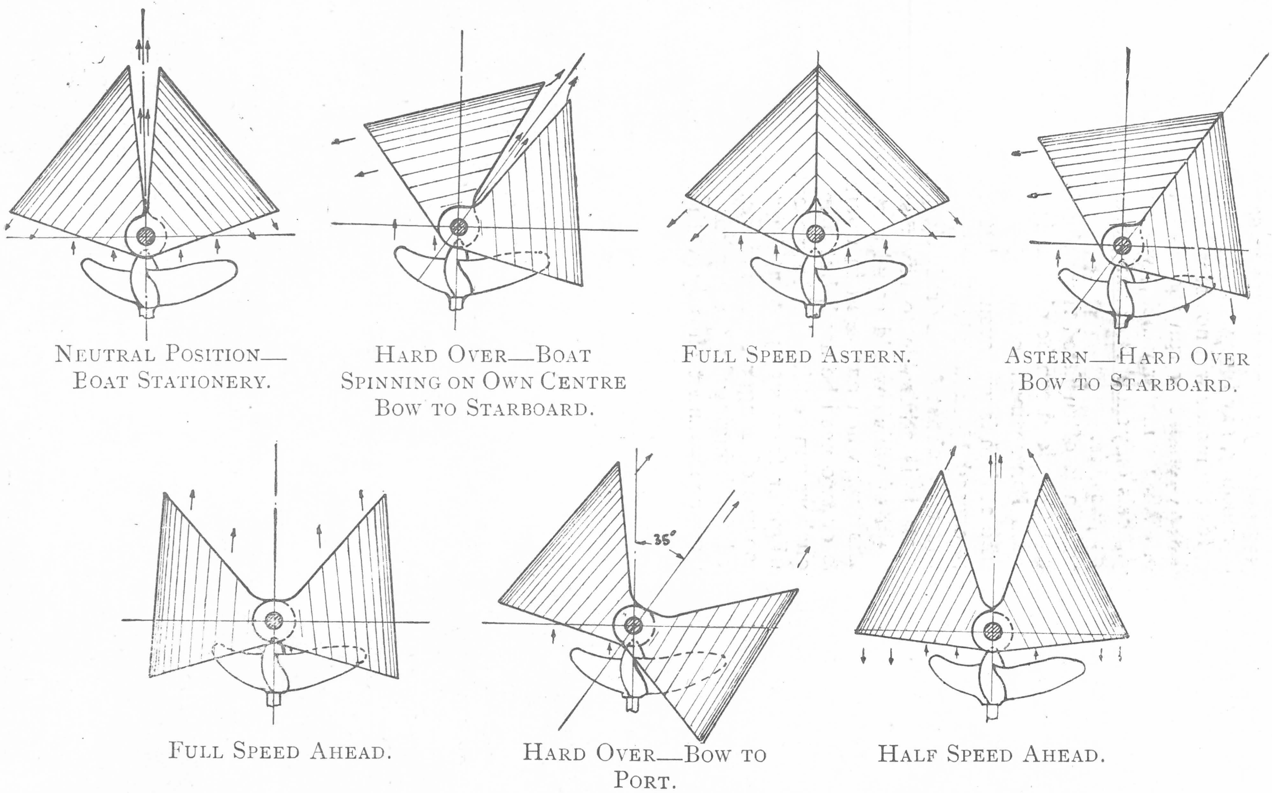
bevel gearing, these have by no means given satisfactory results. Another method of running, say four winches from one deck motor is not satisfactory, for the motor will not stand a constant variation of load; it will either overheat or run too cold, and require blow lamps all the time. With a motor winch, two warping drums and one or two gipsy wheels only should be arranged, and the load should be kept as even as possible.

A messenger chain is often fitted from the forward winch to the windlass when a clear lead can be obtained; when this cannot be arranged, a small hand winch is used.

The anchors are seldom large, even with the biggest lighters the bowers do not exceed $1\frac{1}{4}$ hundredweights, and if kedges are supplied they are usually about $\frac{3}{8}$ hundredweights. Rather than fit two heavy bowers it is advisable to have, say three anchors the aggregate weight of which would equal that of the two; the advantage of this is that when anchored in rivers where there is little tide only one or two need be used, but if moored in a swift current the other anchors can be "let-go" to prevent any dragging, or to prevent the lighter from swinging athwart the stream and thus becoming a source of danger to navigation. Anchor davits are generally fitted for bringing in the anchor, a mooring pipe being very seldom arranged—and then only with large sea-going craft.

The steering gear is of the double reduction gear type, placed on the bridge, suitable chain leads being led aft to the quadrant. In very small lighters a tiller only is used, but when coming alongside difficulty is experienced owing to the fact that the helmsman has an interrupted view. With large vessels a steam gear may be required, although this would only be necessary with sea-going craft. The quadrant, which is an iron or steel forging, has either three arms and a plate, with the usual guide angles, or is of a single arm flattened out at the end to take the shackles of the leads. Chain buffers are seldom fitted.

A comparatively new type of steering gear and rudder, which has found much favour with barges and lighters, has been supplied to many recent craft, with considerable success. This rudder, made by the Kitchen Reversing Rudder Co., Ltd., consists of two semi-circular vanes which may be manipulated by tiller, wheel, or lever. Not only do these vanes steer a vessel in the same way as the usual flat-plate rudder, but by bringing them together, the vessel may be made to go at half, quarter speed, or be made to stop and reverse, even while the engines be running full speed ahead. See Fig. 68. The advantage of this will be readily seen when one considers that barges and lighters are more or less working in very constricted waters. The advantages of better steering and manœuvring (by adjusting the angle of the vanes the vessel can be made to turn on her own centre), the rapidity and reliability of action, besides the direct control from the bridge



NEUTRAL POSITION—
BOAT STATIONERY.
HARD OVER—BOAT
SPINNING ON OWN CENTRE
BOW TO STARBOARD.
FULL SPEED ASTERN.
ASTERN—HARD OVER
BOW TO STARBOARD.
FULL SPEED AHEAD.
35°
HARD OVER—BOW TO
PORT.
HALF SPEED AHEAD.

FIG. 68.

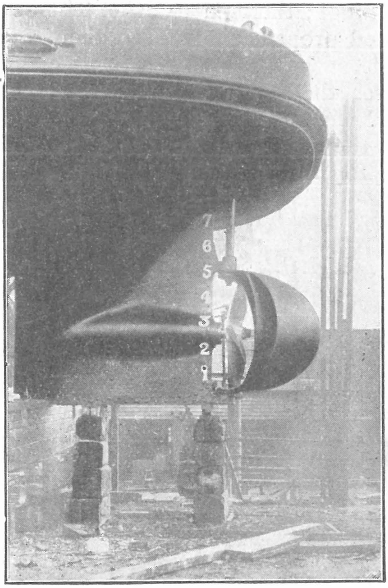


Fig. 69.

and the absence of shock and strain on the vessel makes this rudder particularly suitable for such vessels working in crowded and restricted waters.

Fig. 69 shows the stern view of a 300 ton lighter fitted with these rudders, and during her trials at Grimsby her performance was remarkable. Full speed ahead to full speed astern was accomplished in 18 seconds, while at half speed she could turn on her own centre in two minutes. This type of reversing rudder should appeal to owners of craft working on inland waters, especially where the Captain and Mate jointly perform the duties of Engineers, and too much time in the engine room cannot be allowed.

The powering of lighters has not received much consideration from owners and Naval Architects. Usually with oil engines the great mistake of under powering is made, when if trials are not so satisfactory as was anticipated, blame is more or less attached to the engine rather than to those to whom the installation was entrusted. With small craft the oil engine undoubtedly holds considerable advantage over the steam sets insomuch that fewer hands are required for their working, and considerably less space is required for them such that there is an equivalent increase in the hold space and deadweight capacity. On the other hand, with a slower speed steam set greater efficiency is obtained since there is a great loss of power when high speed engines are fitted

to a slow speed boat; this can to an extent be eliminated with a carefully designed propeller, but even then, the slip per cent. is very considerable.

Fig. 70 gives the speed and power curves suitable for lighters and barges fitted with steam engines, and for information of power with oil engines, the reader is referred to Chapter 5, dealing with barges. The formula on which the curves for the steam sets were based is :—

$$\text{I.H.P.} = \frac{6 \times S \times V^3}{100{,}000}$$

Where V = speed of the vessel in knots,
S = area of wetted surface, in square feet.

The value for the wetted surface may be easily estimated by any of the following :—

$$S = 15.5 \sqrt{W \times L}$$

$$S = 1.7\ LD + \frac{V}{D}$$

$$S = (L \times D \times 1.7) + (L \times B \times Cb)$$

Where L = length between perpendiculars, in feet.
B = breadth, moulded, in feet,
D = mean draught, in feet.
Cb. = block coefficient.
V = volume of displacement, in cubic feet,
W = displacement in tons.

Care should be taken in using the second formula since with light draught vessels the value given may be inaccurate, especially should the vessel have a large length-breadth ratio. The Admiralty coefficient formula is often used, but care must be taken with slow speed vessels, since there is a very sharp drop in the curve of coefficients when the low speeds are approached.

The propeller requires special consideration, since there is a great difference between the screw driven by the steam set and the oil engine. With the former a pitch diameter ratio of 0.8 to 1.05 is usual; it should not be below 0.7, except when a high speed steam engine is fitted. The pitch angle will be quite normal if the diameter is kept compatible with the pitch, and thus inefficiencies, etc., will to an extent be eliminated. With speeds between 3 and 7 knots, the slip is somewhat high, often above 40 per cent., and with the oil engine, often above 50 per cent. With slow running engines, however, the normal slip is generally about 10 to 15 per cent.

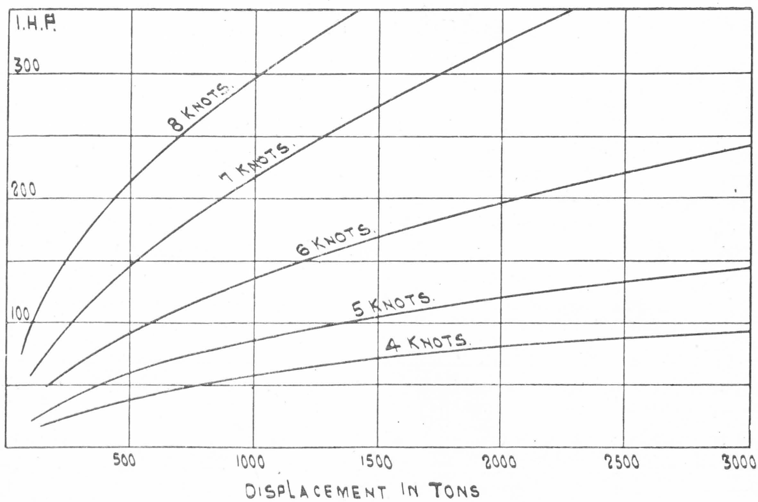


FIG. 70. SPEED AND POWER CURVES LIGHTERS.

The shape of the propeller blade is open to considerable controversy, some designers preferring the normal leaf-shaped blade, while others are in favour of the blade with a broad tip and comparatively narrow root. The best results are obtained, however, when the greatest breadth of the developed blade is in the neighbourhood of 2/3 the diameter, and generally, the greater the speed of the propeller, the greater distance the greatest width of blade is removed from the root. These propellers require greater care in casting, etc., and often on account of the first cost, owners favour the more normal and easier type of blade. See also Chapter dealing with propellers for barges for proportions of propellers, etc.

Although the initial cost is somewhat greater, twin sets of engines are often installed owing to the fact that with equivalent horse power the length of the engine room may be reduced, thus giving a greater hold space. With oil engines this is particularly the case, and besides the point of view of increased deadweight, the total efficiency of the twin screws considerably exceeds that of the single propeller. If the after lines are fine, however, it may be advisable to instal a single set of machinery since insufficient width of floor would necessitate the twin sets being removed some considerable distance forward.

CHAPTER 8.

LAUNCHES.

Although steam launches had been in service for a considerable period, it was not until the beginning of the present century that motor launches became a subject for the careful consideration of Naval Architects. It was owing to the fact that these early motor boats were capable of speeds hitherto unaccomplished by steam vessels of similar size, that the attention of the public was attracted. With the rapid development of the petrol-electric engine for the motor-car, came a corresponding development of this type of engine for marine work. These racing boats, showing up all defects of design in the hull and engine, brought about a rapid improvement, greater seaworthiness, and with commercial interests closely following the path of the pleasure seeker, we find, in 1906, a speculating firm building a little 10-ton cargo-carrying launch. 1907 and 1908 reassured the value of the marine motor for this class of boat, and with continual improvements, it is not surprising to find that nowadays it is the exception rather than the rule to find launches installed with the old-fashioned high speed steam engine with the small vertical boiler.

The diversity of conditions and employment to which launches are now put, makes it an impossibility to detail each type separately in the space allotted for this class of boat, sufficient must it be to treat only of the most common, and, generally speaking, these can be divided into the three following classes :—

Type I. SEA GOING LAUNCHES, *i.e.*, those employed upon the coast for making short trips, etc.

Type II. HARBOUR LAUNCHES, *i.e.*, those employed on exposed waters, and in harbours.

Type III. RIVER LAUNCHES, *i.e.*, those employed upon sheltered waters.

These three types may be further divided, each into :

(a) Launches employed in carrying cargo,
(b) Launches employed commercially, for carrying passengers,
(c) Private pleasure launches,
(d) Towing launches, etc.

It was quite common in some of the earlier types of launches, those with very fine ends and an inclination to hollow bilges towards the midship section, to find considerable differences between the prismatic and block coefficients, which when used

with new boats for comparative purposes, would often lead to a great amount of trouble. The block coefficient of present-day launches varies considerably with each type. For pleasure launches it generally lies between 0.3 and 0.45, although with some very fine boats it is often below 0.25, and on the other hand, with the boats intended to carry cargo or a large number of passengers, it will often be as high as 0.65. The prismatic coefficient, which forms a greater guide for computing estimates, etc., generally lies between 0.4 and 0.6, of course, exceeding these figures for the cargo-carrying, or the very fine racing launch. As a guide, the following table may prove useful for estimating the approximate prismatic coefficients of our three types of launches :—

Type I	(a)	0.6—0.65	(b)	0.45—0.65	(c)	0.4—0.6
,, II	(a)	0.6—0.65	(b)	0.45—0.6	(c)	0.4—0.6
,, III	(a)	0.5—0.65	(b)	0.4 —0.6	(c)	0.3—0.5

With launches, and some types of yachts, it must be noted that the block coefficient is worked upon the waterline breadth of the boat, and the prismatic coefficient, except with the very broad transomed racing boats, is calculated at the section of greatest immersed area.

Some years ago, an authority upon launch design, expressing the prevailing opinion of his time, said that, when discussing the shape of a boat, it was necessary to have a boat somewhere, and the sooner it was over, the better. He implied that full bows, getting the greatest immersed section well forward, and a particularly long and fine run aft to the propeller were essential for speedy, stable, and economical boats. Modern opinion does not confirm this idea, and, moreover, experiment and experience prove that the reverse is the case. The greatest section should be substantially aft, and, for example, one may cite the recent fast launches which have passed successful trials. These boats, of French and American design, have very fine water lines forward (although the deck lines are excessively full owing to the great flare of the forward sections), and their point of greatest waterline beam is at the transom, the load waterline being more or less triangular in shape. Strictly speaking, the greater the speed of the boat, the further aft becomes the point of greatest beam, although for the types of boat which we are treating in the chapter, it is usual to provide the point of greatest beam, and, therefore, the section of greatest immersed area, at about 0.05 to 0.025 of the waterline length aft of amidships for boats of Type b and d. With Type c, where a turn of speed may be required, the proportion may be increased to 0.10, or even in some cases, to 0.15.

Launches, as a rule, are designed upon a geometrical curve of areas. It is not intended to explain here the mathematical significance of this curve, sufficient is it to mention that waves displaced by a vessel moving in water follows the curve of versed

sines, and according to theory, the curves of replacement are of trochoidal form, and in consequence, the curve of areas of the transverse sections, if following these curves, should give the most economical form of under water body for a vessel. Let us proceed to construct such curves. The generating circle, the diameter of which should represent the area of the greatest immersed section, should be placed at the suitable distance abaft the midship section, and for practical purposes there should be an allowance of $2\frac{1}{2}$ per cent. of the length of the boat on the length of the curves at each end. Reference to Fig. 71 should make the construction of these curves quite clear. A.B. represents the length of the boat, whilst A′B′ is the length of the curve allowing the $2\frac{1}{2}$ per cent. previously mentioned. The diameter of the generating circle, which here is shown amidships, represents the area of the greatest section. The circumference is divided by seven equidistant points, J.K.L.M.N.O. and P., and A′F and B′F. are each correspondingly divided equidistantly by three ordinates, C., D.E., and G.H.I. The points K.L.M., are produced parallel to the base so that they intersect at the points T.U.V., T.G., U.H., and V.I., being perpendicular to the base A′B′. The curve passing through the points J.T.U.V. and B′ give the curve of versed sines, which will be the curve of areas for our forward sections. To obtain the curves for our after sections, the points P.O.N. are joined to the point F., and the ordinates SE, RD, QC, are drawn parallel to these lines, respectively. The points P.O.N. are produced parallel to the base, and at the intersection with the ordinates, the points for the after curve are obtained. The area at any section can now be easily obtained by simply erecting an ordinate at the point required, and measuring its length with the same scale as was used with the generating circle.

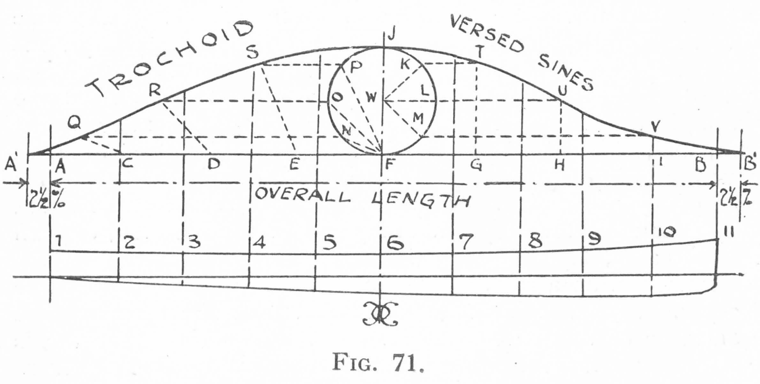


FIG. 71.

The position of the Centre of Buoyancy is to a great extent governed by this curve, but many Designers make some modifications whereby the C.B. can be brought into the position they wish. There is considerable variation in its position with different classes of launches, and there are a number of opinions among Launch Designers, some prefering the C.B. to be forward, and others for it to be aft of amidships. The position, however, is more a matter of compromise, and more often than not, the correct draughts, etc., are made up by ballasting, in the pleasure boats, and by trimming, etc., in the case of the passenger and the cargo launches.

With launches plying in exposed waters, the forward sections should be a combination between the V and the U forms.

V-shaped sections, while giving a fine speedy entrance, lack ability to give the necessary lifting power and buoyancy, whilst U sections giving ample buoyancy produce a clumsy cntrance and would make a most uncomfortable boat, owing to pounding. To have the V sections merging into the U or to have one superimposed upon the other, produce an economical, efficient and comfortable forebody.

There is a great difference in the shape of midship sections for different classes of launches. Passenger launches working under Types I and II, have fairly full sections, with a good round of bilge, and considerable rise of floor, while launches working upon rivers (Type III) and where there is usually some restriction on draught, have practically a flat floor and very hard bilge. Tumble home is not desirable, nor is it necessary, except in very high-speed boats.

Launches with built-up sterns, *i.e.,* counter and canoe sterns, should possess a fairly fine run aft to the propeller, which, of course, will give rise to hollow bilges in the after sections, but with transom-sterned launches, and with those having the slipper, or such like stern, both the waterlines and the sections are very full.

Fig. 72 gives the sheer draught of a vessel of Type I, and Fig. 73 that of a vessel of Type II. Their differences in character may be easily seen. With the smaller boat, the after body, it will be noticed, is much fuller, and the same will be seen with the sections of the river launch, given in Fig 74.

A good sheer is needed for vessels which are intended for service around the coast, or at the mouths of large rivers, but with the smaller river craft, sheer is more a matter of appearance than necessity. For launches coming under the Board of Trade survey, of certificate, there are certain requirements. Vessels plying under the Class St. 6. certificate need a minimum freeboard of 15 inches when fully loaded, for a vessel of 20 feet in length, increasing proportionately to 22 inches for a vessel of 40 feet in length. This freeboard is measured to the top of the covering

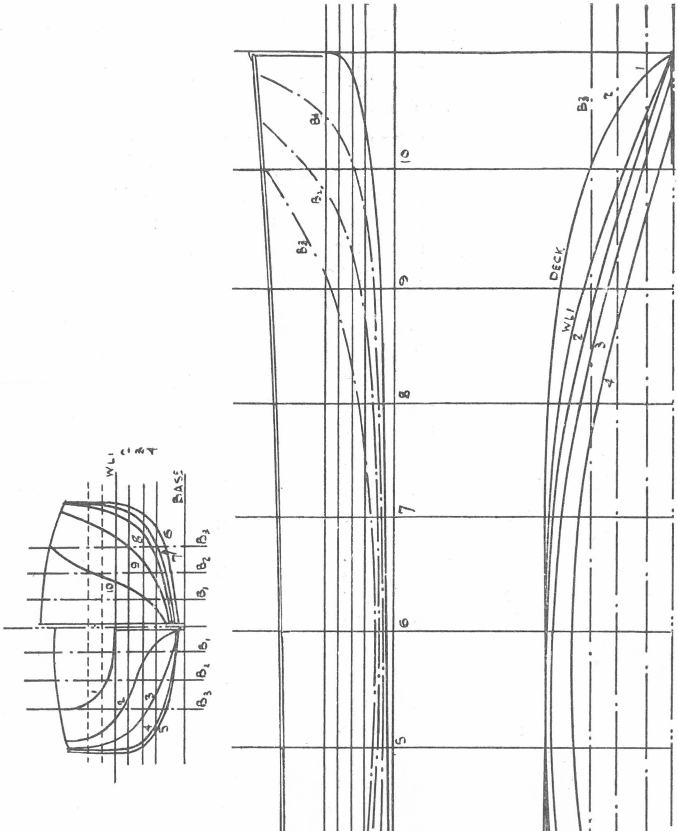


FIG. 72. SHEER DRAUGHT PASSENGER LAUNCH.

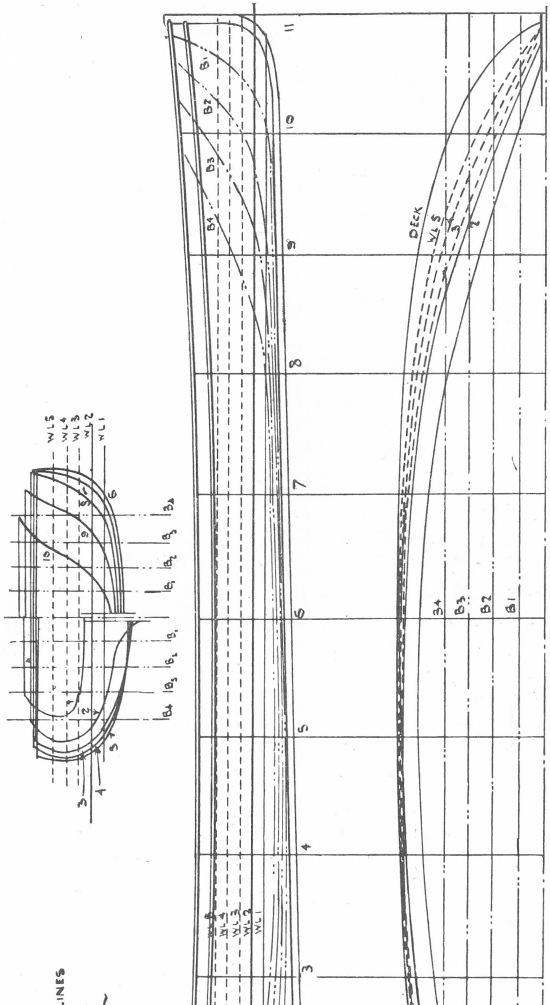


FIG. 73. SHEER DRAUGHT PASSENGER LAUNCH.

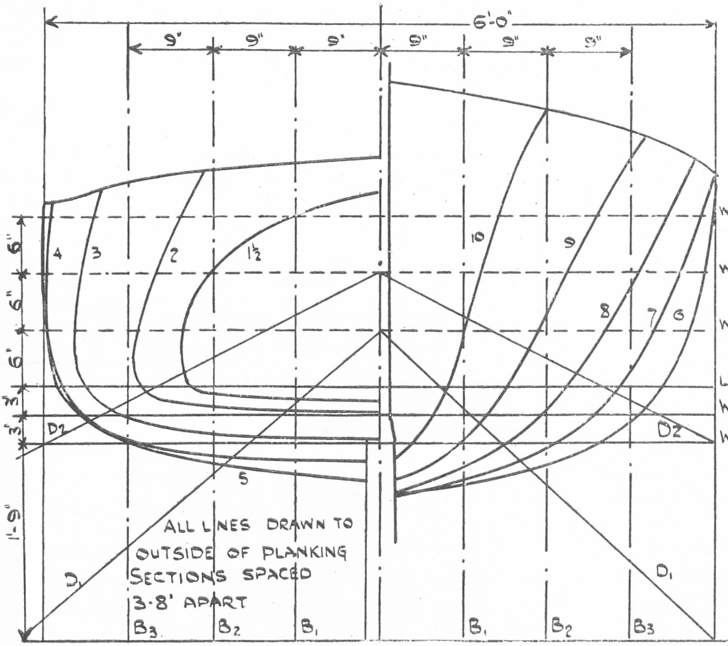


FIG. 74. BODY PLAN RIVER LAUNCH.

board, or to the deck at side. The sheer must be substantial, and sufficient to provide a dry fore deck in normal weather.

Stability with the larger launches is an important consideration, and while it is most uncomfortable to have a very "stiff" boat, it may be equally uncomfortable to have a boat where the stability is not assured. With a normal set of lines, however, there may be little to worry in this direction.

Since all vessels which carry more than twelve passengers, come under the Board of Trade Regulations, it may be advisable to mention here some of their main requirements, which affect this class of boat. A special certificate, the St. 6., embraces motor launches "plying on short excursions to sea in summer, in daylight, and in fine weather."

The minimum depth, measured from the top side of the coaming board to the top of the flooring, is 30 inches for launches up to 20 feet in length, increasing to 36 inches for a boat of 40 feet length. In decked craft a bulwark or rail must be provided not less than 3 feet 3 inches in height.

Water-tight bulkheads, lined with ¼in. asbestos, and covered with stout galvanised steel sheets, must be provided to divide the motor from the passengers.

It is advisable to furnish the Board with plans and specification of any new or proposed vessel, and it is also necessary to be prepared to give trials, as the Board may need stability and manœuvring tests.

The total number of persons a boat plying under this certificate is allowed to carry is given by the result obtained by dividing the clear space allowed to passenger accommodation by 4. But fixed seating accommodation must be allowed for both crew and passengers (the space of 1 feet 6 inches is allowed for each person) and should the figure given by the rule be greater than that allowed for by the seating accommodation, the smaller must be taken. Passengers are allowed to sit each side of the engine, providing there is a space of at least three clear feet, and providing such space is divided off by water-tight bulkheads, lined as before mentioned.

Besides the usual equipment of anchors and cables, craft plying under this certificate must be supplied with some form of buoyant apparatus capable of supporting at least 40 per cent. of the number of passengers and crew carried. Preference is given to apparatus which takes the form of buoyant deck seats. Small boats up to 26 feet in length may have lifebuoys in lieu of the above, at the rate of one per person. Two lifebuoys must be supplied to vessels up to 30 feet in length, and four for vessels up to 50 feet.

In addition to the above, equipment such as three pairs of oars, mast and sail, compass, etc., must be supplied.

The limits of the plying area for boats of the class may be exceeded under certain circumstances, when a St. 6. Extended Certificate is given, but such is under the entire control of the local Board. Boats under this certificate must have ample freeboard and sheer, while stability and speed must be assured. It is well to note that twin-screw boats are treated very favourably, for obvious reasons, by the Board. These boats must be decked for at least one fifth of the length forward, and must have buoyant apparatus to 80 per cent. of the total number of passengers and crew. The number of passengers is deduced by dividing the clear deck space by 6, and the area below deck, *i.e.,* that which is for passenger accommodation, by 9, or by allowing 1ft. 6ins. of fixed seating for each person. At least one W.C. must be provided, and allowance must be made for reasonable privacy.

Launches may come under other classes if their service be such as coasting or working in harbours, etc., and for information upon this the reader is refered to Chapter 9 on Passenger Vessels

Curves of dimensions, etc., for Type I are given in Fig. 75, and for Type II and III in Fig 76.

The "Dorothy White," Fig 77, is a rather large type of passenger launch, which was designed for service on the South Coast. One large saloon is situated aft, at the forward end of

which is the ladies' and gents' toilet. The engine room is amidships, forward of which is the Galley, which leads directly into a small dining saloon. The crew are accommodated abaft the small chain locker. Except for the steering house, which is situated above the engine room, the deck is almost clear for passenger accommodation.

The arrangement of the "May," Fig. 78, shews a somewhat smaller vessel coming under Type II.

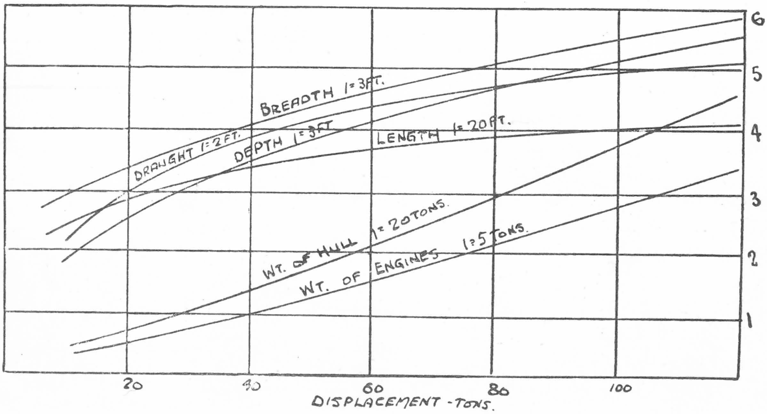


Fig. 75. Curves of Dimensions, etc. Steel Launches.

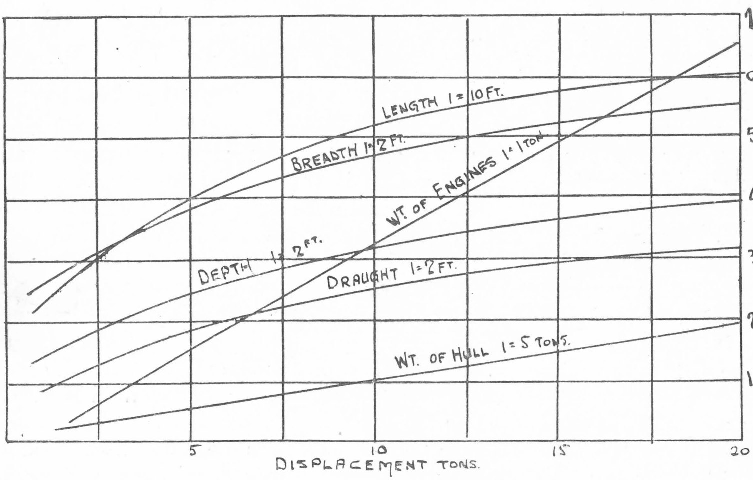


Fig. 76. Curves of Dimensions, etc. Wood Launches.

Here the engine is situated well forward under a casing, which will pass the Board of Trade, providing it is efficiently made. The fuel is stored in circular tanks strapped to the beams under the forward deck. A long cockpit accommodates the passengers, and it will be noticed that by the arrangement shown, the greatest seating is obtained.

A usual type of river launch is shown in Fig. 79, The engine again is situated forward, while at the end of the lengthy forward cockpit is fitted a small house, complete with two sofa-berths, cupboard and stove. Another cockpit is abaft the house, and a small locker for spares, etc., is fitted under the after decking.

Although steel is gradually being used for some classes of launches, the construction is still mainly made in wood. For small craft, wood has a distinctive advantage over steel, insomuch that the construction is both lighter and cheaper, and, to a degree, simpler. Steel plating for launches is of very light scantling, and is apt to show any light damage it may receive, and so after a season's hard work, would present a very unsightly appearance, and also, steel, having a greater conductive power of heat, would in summer, make a small cabin almost unbearable. It would be impossible to define any limit of where wood vessels should finish, and steel commence, it is more a matter of conditions of service.

In wooden boats, the keel and hog-piece should be of Oak, or other hard wood, although Pitch, Oregon and Kauri Pine are used in some of the cheaper boats, and in some large vessels English Elm is sometimes used with satisfactory results. Stem and stern pieces should be of natural grown Oak crooks well scarphed to the keel or hog-piece, and well through fastened with yellow metal bolts. The floors, which are of grown Oak crooks, should be of sufficient length to take one through fastening with the bilge stringer. In larger craft, steel plate floors are often used with advantage, and these, of course, must be galvanised, preferably by the hot-process, after working.

Except with small vessels, up to about 40 feet in length or to 50 feet in river craft, cut timbers of English Oak, spaced at about 4 feet apart, centre to centre, form the main framing, smaller steam-bent frames of American Elm being worked between to stiffen the outside planking, and to supplement the main framing. These small bent timbers should extend from gunwale to gunwale, in one piece, passing over the keel or the hog-piece, wherever practicable.

Beam shelves, stringers, etc., which should be of American Elm or of Pine, should be fitted on the face of the cut-timbers, if these are fitted, or on the face of the bent timbers; they are through fastened with copper nails, of substantial size, and clenched over on the inside, on copper rooves. Longitudinals should be carried the whole length of the boat; scarphs should

be long, and well through bolted, care being taken to see that such scarphs are well shifted, and not opposite each other, and they should all be well connected forward by grown Oak breasthooks. Greatest importance should be attached to the longitudinals as it is upon these that the main framing of the launch depends.

The deck beams are generally of Oak, Larch or Pine, dovetailed into the beam shelf, and well spiked down. In larger vessels, with continuous decks, galvanised iron hanging knees should be fitted, at least 8 feet apart, and the designer must see that the beam comes reasonably near to a sawn timber so as to provide efficient connection.

In the better class of boat where it is desired to varnish the sides, mahogany and cedar are used for the planking, but both of these woods are very expensive. Oak is only used with the larger of the launches, and sometimes American or English Elm is worked into the bottom and the bilge planking, and acts very favourably providing they are not constantly out of the water, and thus open to quick rotting. The most common woods in use, however, are Larch, Oregon, Pitch, Kauri, and sometimes White Pine. There are three methods of fitting the planking, known as Clinker, Carvel, and with the multiple-skinned boats, double diagonal. The three systems are shown by Fig. 80. The Carvel system consists of fitting the planking edge to edge, and stopping and caulking the seams. Cotton is generally used for caulking, and Marine glue or pitch for paying. In the better class of boat the joints are carefully fitted so that caulking and paying is unnecessary. The Clinker or Clencher is commonly used in small, cheap boats, and while not presenting such a good appearance, give a strong and elastic construction. With the uneven surface there are considerable resistances set up, and proportional reductions on speed. The system consists of lapping the lower edge of the strake over the top edge of the lower strake, and the joints thus made do not require stopping nor caulking. The multiple skin, as the name implies, consists of two or more thicknesses of planking. Where two thicknesses are fitted, they are fitted diagonally at right angles with each other. Sometimes only one, the inner, is fitted diagonally and the other horizontally as with the carvel build. In all cases the planking is through fastened at every frame by copper nails clenched over rooves on the inside, except with the multiple skinned boats which are sometimes built on longitudinal stringers.

The deck planking is generally of pine or larch, except with boats intended for Tropical regions when teak is used. The centre or king plank should be of mahogany or hard wood, and the planking is laid from the centre so as to allow for secret fastening. The covering board, which is of hard wood, forms an equivalent to a stringer plate in steel vessels, and should be well fastened down by means of screws, so as to form a good connection with the beam shelf.

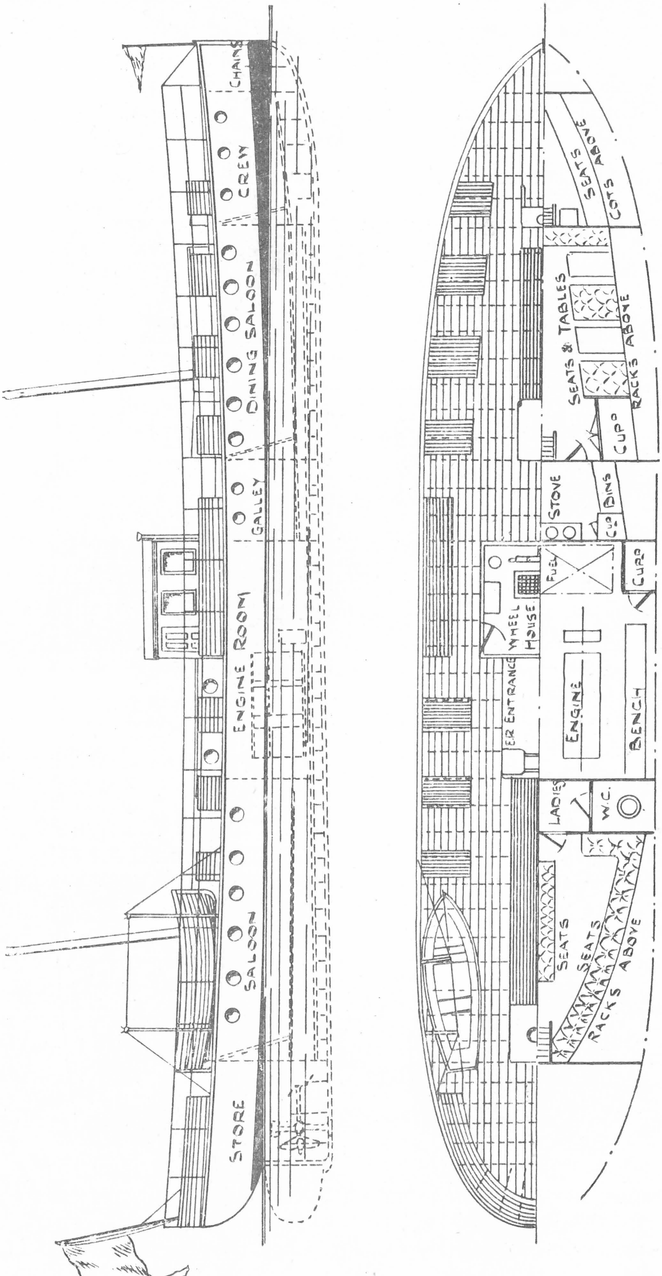


FIG. 77. GENERAL ARRANGEMENT "DOROTHY WHITE."

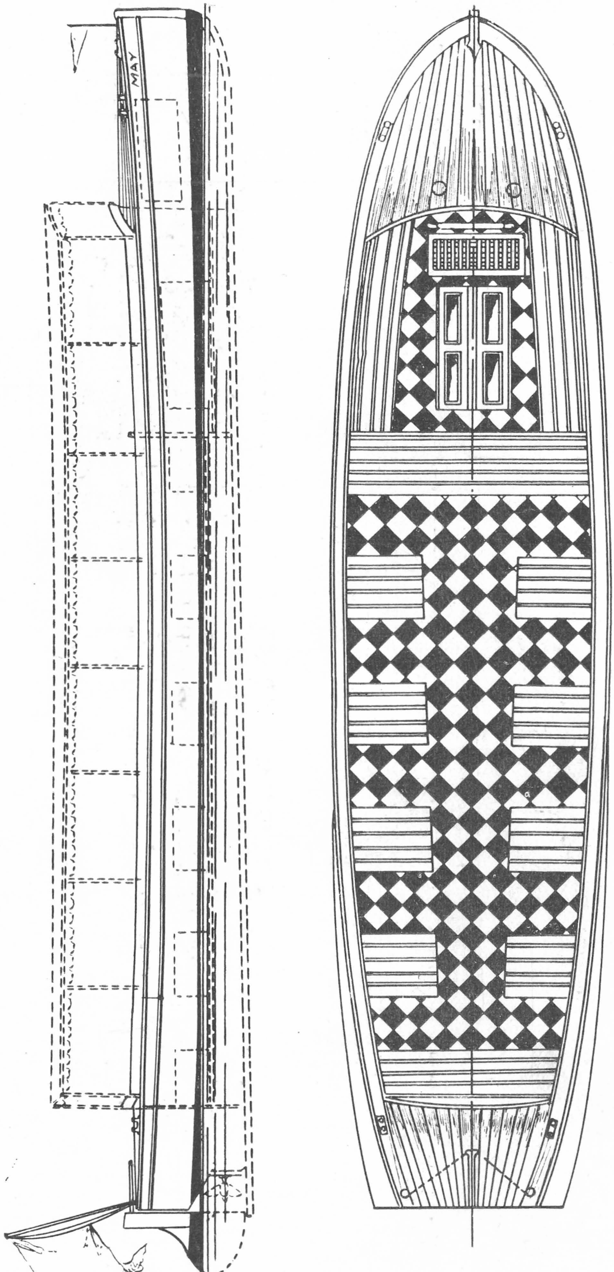


FIG 78. GENERAL ARRANGEMENT "MAY."

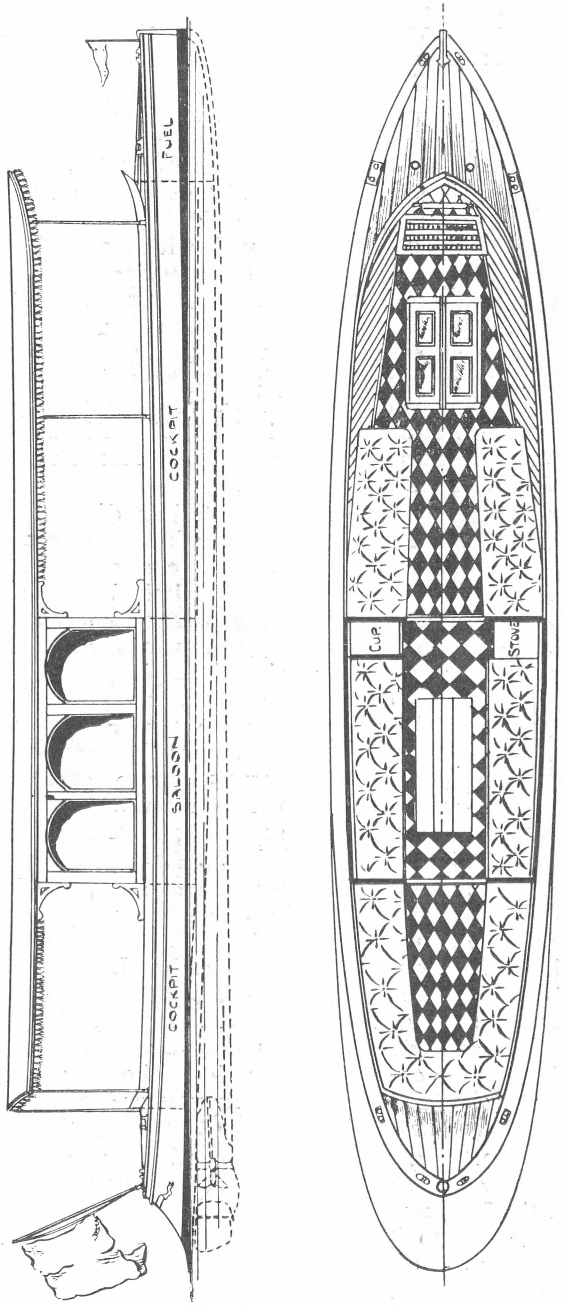


FIG. 79. GENERAL ARRANGEMENT RIVER LAUNCH.

Bulkhead planking, flooring, seating, etc., are usually of pine, although seats and other parts exposed to view are, for the sake of appearance, of hard wood.

Fig. 81 gives a common midship section of a launch working under Type II. or III. The keel and hog-piece, it will be noticed, are separate, in two pieces, the advantage of this method being the easiness of repairs should the keel be torn away. A similar method is employed with the stem. The planking forward is fastened to an apron piece against which it fays, and the stem, which has no fastenings with the planking, is simply through bolted with the apron piece. The midship section of the "Dorothy White" is given in Fig. 82. The steel construction is of fairly light scantlings. The framing consists of $2'' \times 2'' \times 3/20''$ angles, and the plating throughout is $3/20''$. Single angles are employed for the stringer and keelsons, while double keelson angles are fitted to the centre intercostal keel plate. A $3/20''$ stringer and centre tie plate are fitted on the top of the beams, and a wooden deck of $1\frac{1}{4}$ ins. larch is laid.

The construction of launches in steel is of a very simple character. The two most important considerations are the provision of ample lateral rigidity and ample strength of bottom. When launches are open or only partially decked, the tendency to transverse deformation, and the various racking stresses experienced, especially if the boat be working in partially smooth water, may produce dangerous results should ample provision not be made. Floors should be of ample depth, and be carried round the turn of bilge. The reverse bars are sometimes carried only along the tops of the floors, and sometimes they are not fitted at all, the top edge of the floors being flanged to serve as reverse bars. These may suit quite well with boats working in sheltered waters, but it is advisable with sea-going craft to continue the reverse frames up to the heads of the frames.

The keels are generally of bar iron or steel, and flat plate keels are only introduced into the large boats. Longitudinal stiffening is made up by angle keelsons and stringers fitted continuously as far forward and aft as possible. Intercostal keelson plates are only fitted to large boats, where the breadth of the bottom warrants some additional support. In the majority of steel launches the deck angle is under the beams, so that a covering board can be fitted to the wooden deck instead of having the usual water way. This method gives a slightly greater deck space, which is important with these smaller boats.

A very important point with both wood and steel craft, is the provision of efficient and rigid engine seatings. Although the diameter of the flywheel with some makes of engines will not allow the engine bearers to be carried forward, it is most important that the longitudinals should be taken as far forward and aft as possible in order to distribute the weight and strain of the

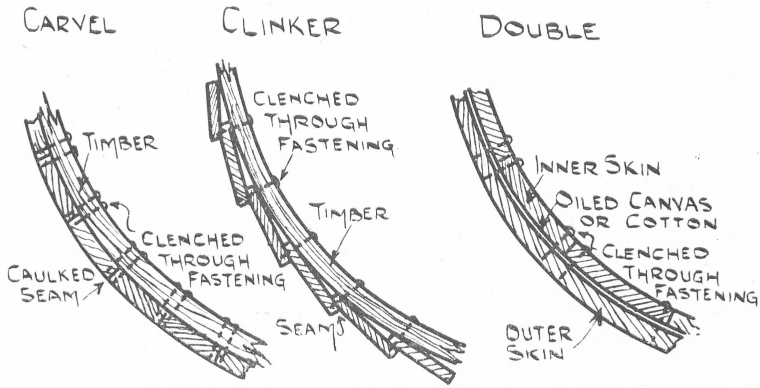


FIG. 80. SYSTEMS OF PLANK FASTENINGS.

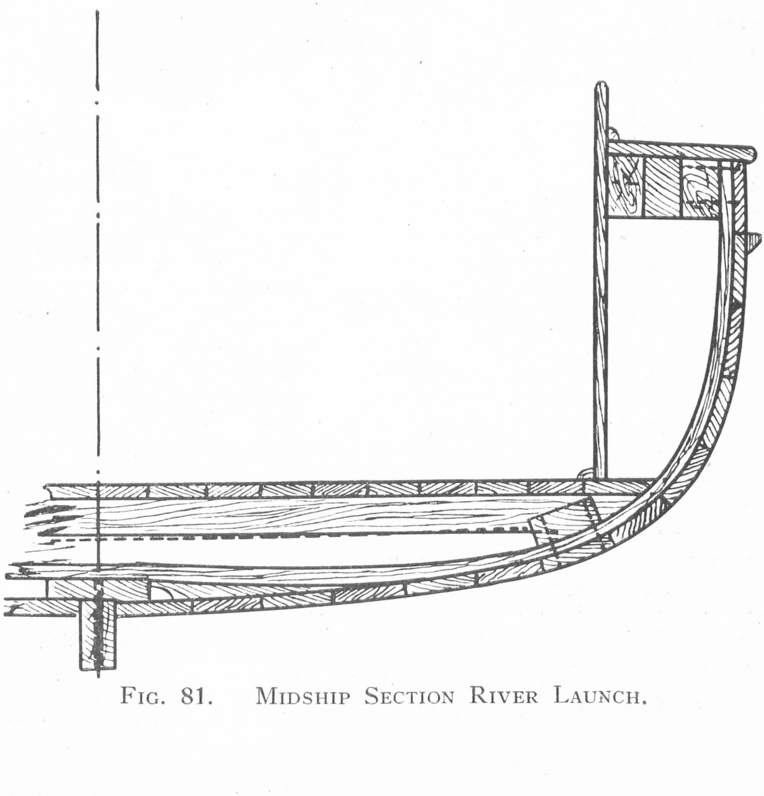


FIG. 81. MIDSHIP SECTION RIVER LAUNCH.

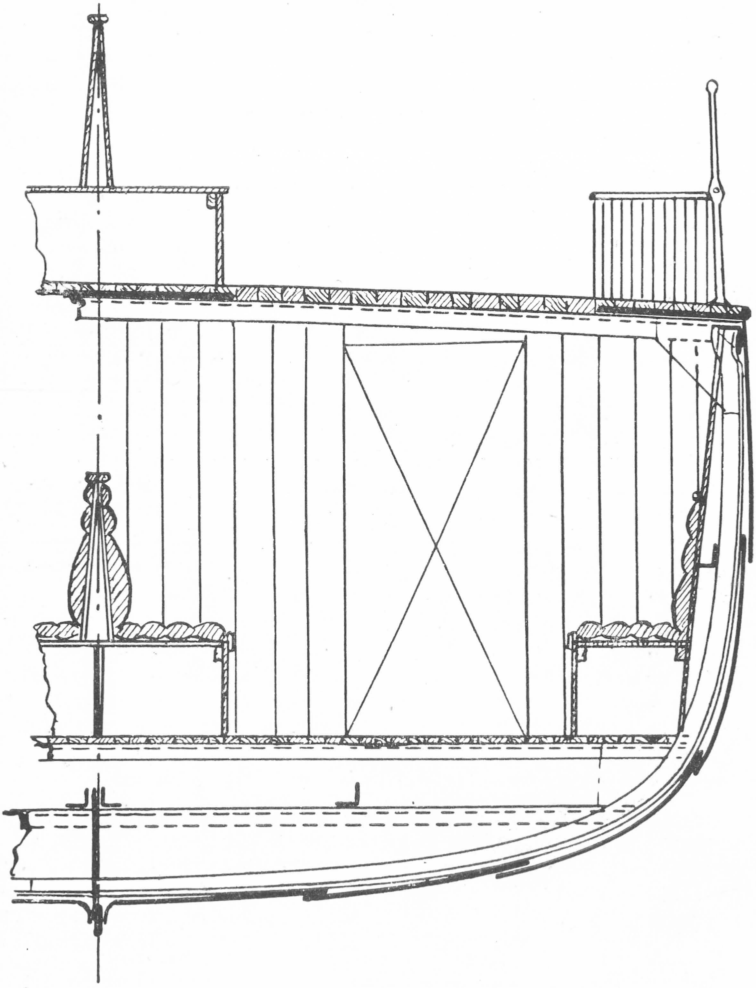


FIG. 82. MIDSHIP SECTION "DOROTHY WHITE."

engine equally over the area of the bottom. The scantlings of the boat's construction is in any case comparatively light, and any lack of rigidity of longitudinal or transverse bearers will cause bad vibration and working. With wood craft the bearers should be joggled over the frames and floors, and through bolted with the shell planking, to give the necessary lateral rigidity. Oak knees or struts should be fitted sufficiently long to take a fastening with the bilge stringer.

Engines in steel launches are carried on angle bars, which should be carried forward and aft as far as practicable. The

bearer angles are attached to longitudinal vertical plates which are connected with floors by angle lugs. Between the vertical plates bracket plates are fitted to prevent the vertical plates from tripping inwards. For further information on seatings, etc., see Chapter 18 dealing with motor installations.

Deck arrangements are generally of a simple character. Where there is a short deck forward and aft only bollards and fairleads are necessary. Sometimes a small ratchet windlass is situated forward for hauling in the anchors, although these may always be hauled in by hand with these smaller boats. With larger decked launches the usual type of windlass is fitted. The anchors seldom exceed 70 lbs and when stern anchors are supplied they are usually about 28 lbs. in weight. In small river craft the anchors vary between 14 and 26 lbs., and are usually stowed in the forelocker.

Steering arrangements should be as simple as possible, and in small open boats the tiller seems to be preferred, although when the engine is situated well forward, wire leads from the tiller are led forward to a small hand wheel, as it is usual for the steersman to take charge of the engine. With larger launches a reduction gear is sometimes needed, and galvanised iron wire leads are brought aft to engage with the circular quadrant.

Having discussed the types of passenger launches, we must now give a little consideration to the cargo and towing launch. The former class of boat has gained considerable popularity in some districts where carriage of goods is a difficulty. These vessels having full lines allow the engine to be placed well aft, thereby allowing the forward part to be used for cargo space. Fig. 83 gives the arrangement of a 10 ton launch.

A small deck is fitted forward for stores, etc., and the cargo space is left clear and open, as it is usual not to deck and fit hatches to these boats, but simply cover the cargo by a tarpaulin attached to cleats or eye screws in the side coaming. The after cockpit holds the engine, and there is accommodation for about a dozen persons. The fuel is stored in circular tanks strapped to the underside of the after deck beams.

A general arrangement of a towing launch is shown by Fig. 84. Here the engine is situated amidships, and is protected by a turtle deck. At the after end of the engine space is situated the small cockpit, while the after peak is utilised as a general store. Sometimes a towing hook is fitted on the after deck, although it is the more common method, and the better, to fit two samson posts at each corner of the after cockpit. This allows the posts to be carried down and bolted with the floors, and allows galvanised iron, or wood knees to be fitted, thus ensuring an efficient connection with the vessel. Hot-bulb engines are often used for this class of vessel, and they show a considerable advantage over the petrol-paraffin motor owing to their weight and power.

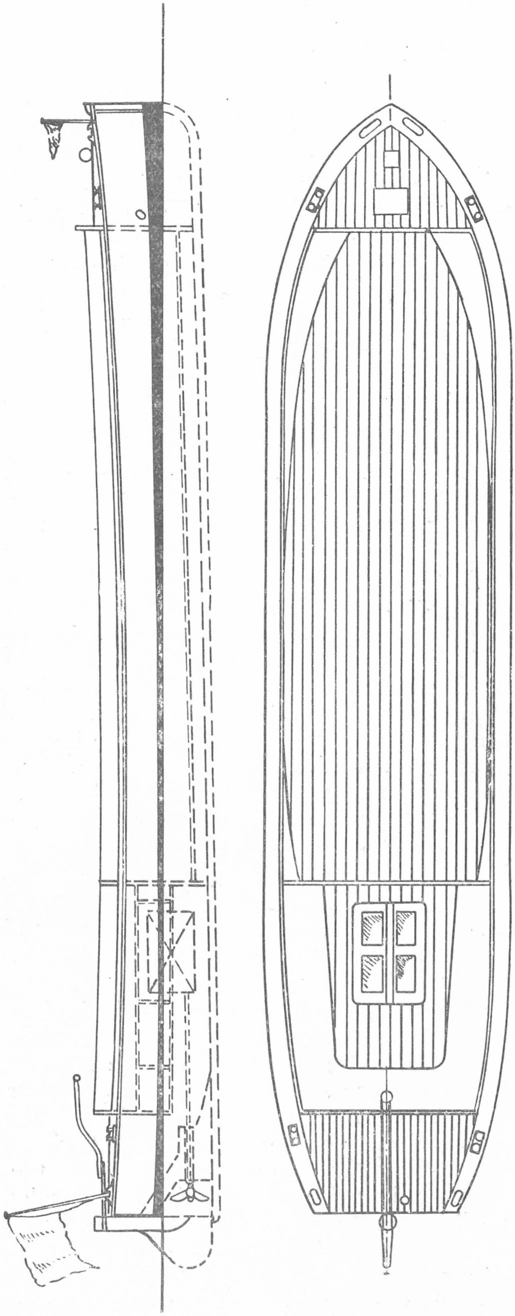


FIG. 83. GENERAL ARRANGEMENT 10 TON CARGO LAUNCH.

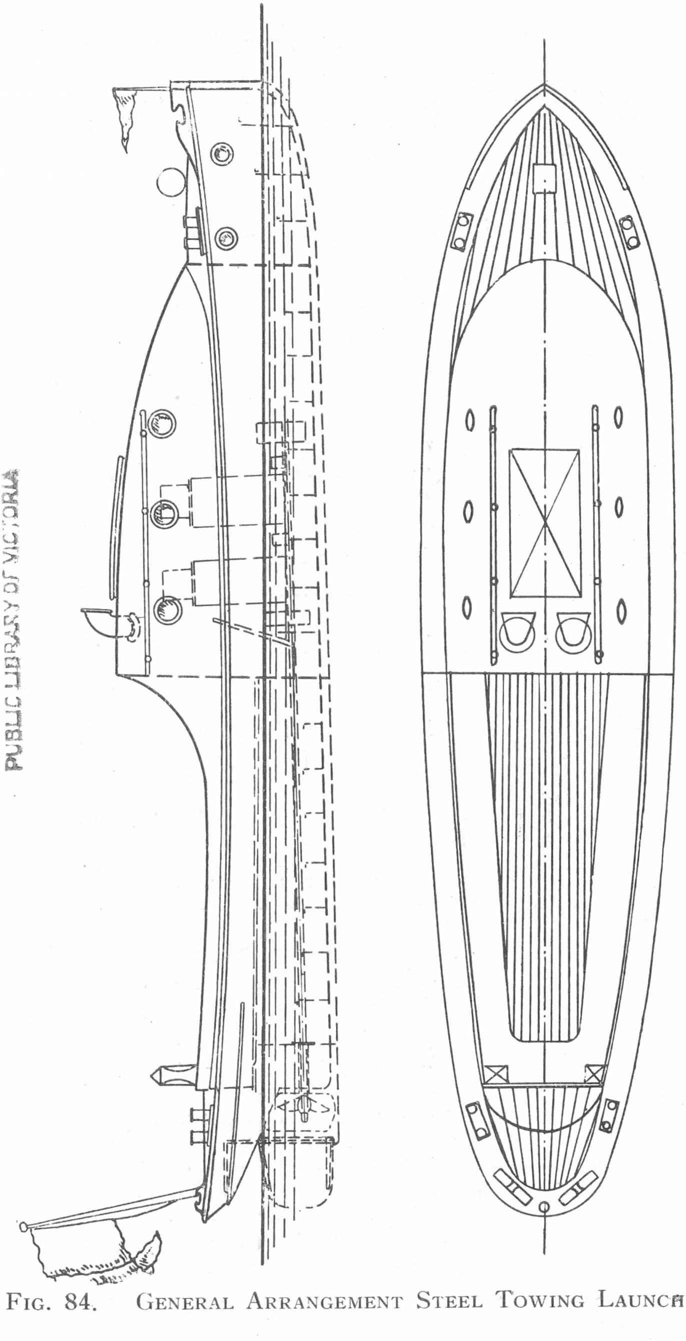


FIG. 84. GENERAL ARRANGEMENT STEEL TOWING LAUNCH.

The powering of launches is an important and difficult problem. Many launch owners require high speeds owing to their greater advertising value, while on rivers there is generally a Conservancy Board which imposes some speed limit. However, it may be safe to say that the normal speed of a launch lies between 6 and 8 knots. Fig. 85 gives speed and power curves for launches of Type I. and II. These are based upon vessels having fairly fine lines, and with prismatic coefficients as shown in the table on page 111. The admiralty coefficient formula, $\text{I.H.P.} = \dfrac{D^{2/3} \times V^3}{C}$ is often used for computing horse power, although it is necessary to make some allowance, generally about 10 per cent., for using the B.H.P. instead of I.H.P. The midship area is often used instead of the two-thirds power of the displacement, in which case, the coefficient, $C = \dfrac{A \times V^3}{\text{I.H.P.}}$ and varies between 100 and 250 according to the class of launch. The speed length ratio, $\dfrac{V}{\sqrt{L}}$ lies between 1.3 and 2, for moderate speeds, increasing to 3 and 4 for very speedy boats. A reliable formula for speed and power is given by $M = \dfrac{c\sqrt[3]{L \times \text{B.H.P.}}}{B}$

where, L = the overall length of vessel, in feet,
B = the greatest breadth of the vessel on the waterline, in feet,
M = the speed of vessel in miles per hour,
c = constant varying between 9.5 in moderate speed boats to 8.5 in high speed boats.

The design of the propeller is important, but up to the present there are no reliable formulæ for giving the diameters and pitches, etc., and it is more a matter of experiment to find the most efficient proportions. The high number of revolutions per minute of motors, need a special type of propeller. The small pitch ratios, generally between 0.6 and 0.8, are essential. It is a comparatively

easy matter to determine the pitch of a propeller, since with launches there is usually a slip between 15 and 20 per cent., although this latter figure may be exceeded with some of the very full, slow boats. But having fixed the pitch, the Designer finds himself between two problems which require the most careful consideration. In determining the diameter, care must be taken to see that it is sufficient to give the necessary area, while on the other hand, by increasing the diameter the pitch angle is reduced. It is most essential that the pitch angle shall not be reduced below a practical limit, else an inefficient propeller will be the result, and since in practice an angle of 43 degrees at two thirds of the diameter has proved to give most satisfactory results under all-round conditions, it may be unwise to exceed this. In regard to the diameter of the propeller, many use

Mackrow's formulæ $P = 737 \sqrt[3]{\frac{\text{I.H.P.}}{R^3 \times D^2}}$ and $D = 20{,}000 \sqrt{\frac{\text{I.H.P.}}{R^3 \times P^3}}$

where, P = the pitch of the propeller, in feet,
D = diameter of the propeller in feet,
R = the revolution of the propeller per minute.

Here again the formula was meant for the slow speed steam engine, and therefore some allowance must be made for using B.H.P.

As with most of the fast running propellers, the blade area should be as near the tips of the blades as possible. The greatest width of a developed blade is usually at about two-thirds the diameter, and it is often twice the width at one third the diameter. The blade area generally totals to 0.25 to 0.33 of the disc area, while the centre of area is about at 0.28 to 0.40 of the diameter Fig. 86 gives curves showing the approximate diameter and pitches for propellers up to 1,000 revs. per minute and up to 200 B.H.P.

It will be noticed that only motors have been mentioned as the means of propulsion, and although it is only here and there one hears of steam installations, the reader requiring information on these is referred to the Chapter dealing with River Passenger Vessels. It is general to fit the petrol-electric type of engine in the private passenger launch, although for a boat coming under the Board of Trade for passenger certificate it is essential to instal a paraffin motor, since the Board require motors using fuel with a flash point of not less than 73 degrees Fahr. They allow, however, a small quantity of petrol for starting purposes.

With the larger type of launch, the heavy oil engine seems more suitable, and the heavy oil upon which they run reduces the chances of fire.

For boats coming under the Board of Trade, it is well to note that it is not allowed to have fuel tanks enclosed within the engine room, but to have some special compartment divided off by watertight, steel bulkheads. Efficient trays should be fitted under engine and tanks, and it is essential to see that sufficient fire-extinguishing appliances are supplied. Piping, wherever possible, should be of copper, and the exhaust pipe well jacketed with asbestos roping.

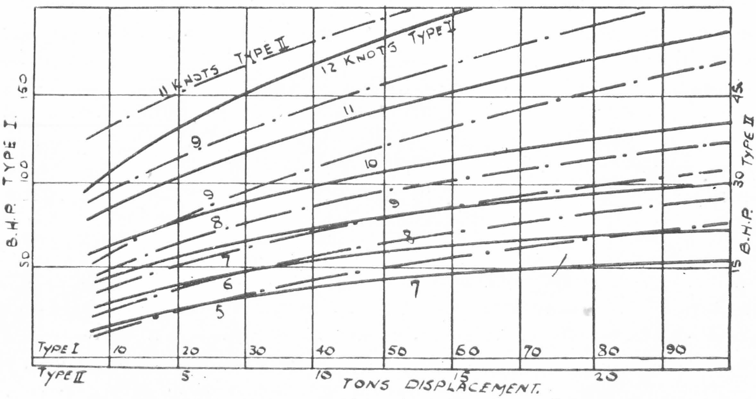


FIG. 85. SPEED AND POWER CURVES, LAUNCHES.

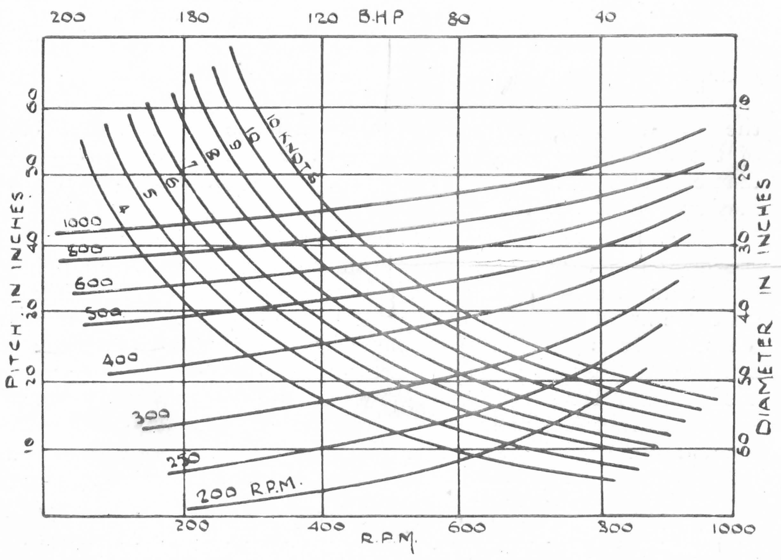


FIG. 86. PROPELLER DIAMETERS AND PITCHES, LAUNCHES.

Chapter 9.

PASSENGER VESSELS.

The idea of passenger boats is always associated with early steamboats, which obtained considerable public attention in the early nineteenth century, and no doubt Robert Fulton can claim by his "Clermont" to have been the designer of the first passenger steamboat. Progress was rapidly made, for in 1810 we find regular passenger services between Scotland and Ireland, from Dover to Calais, besides the numerous services on the Hudson, and other North American Rivers. The idea of the passenger boat was always accompanied with the idea of the large, cumbersome paddle wheel, and although this means of propulsion is still employed in many parts, it is gradually being displaced by the marine screw.

Where a vessel is on service in running short trips, and having constantly to stop at piers or jetties, and where it is necessary to manœuvre in congested waters, the side paddle wheel undoubtedly holds considerable advantage over the screw. If the vessel is working in very weedy parts or where there is only a small depth of water, the efficiency of the wheel exceeds that of th propeller, even should the latter be enclosed within a tunnel, and furthermore, repairs to a wheel are far cheaper and simpler, and it is for this reason that vessels intended for tropical waters, where these are difficult, are almost invariably fitted with the wheel.

All boats intended to carry twelve or more passengers must, before being put upon service, hold a Board of Trade certificate. These certificates are based upon the conditions of service to which it is intended to put the vessel, and it is important here to mention that it is necessary for the designs of all vessels over 35 feet in length to be approved by the Board before construction is commenced, and furthermore, the building throughout should be done under the Board's Surveyor. Failure to do this may incur considerable trouble afterwards, in the granting of the certificate. Of course, if the boat be built under a classification society, the boat comes under the Board of Trade only as far as accommodation and equipment are concerned, although certain statutory rules are laid down in reference to water-tight bulkheads, etc.

The certificates with which we are concerned here are as follows :—

Certificate St. 3., for vessels plying along the coast within defined limits, during daylight, in fine weather, between April 1st, and October 31st.

Certificate St. 4., for vessels plying in partially smooth water.

Certificate St. 5., for vessels plying in smooth water.

Passenger vessels, therefore, are conveniently classified into three distinct types, which for purposes of this book may be as follows :—

Type I.—Excursion vessels, working along the coast under the St. 3 certificate.

Type II.—Vessels working in exposed areas, such as, short coastal work, in harbours, at the mouths of large rivers, etc., under the St. 4. certificate.

Type III.—Vessels working on rivers, and in sheltered waters, under the St. 5 certificate.

Except where it may be intended to carry a considerable amount of cargo, when it is necessary to have a fairly full hull, there is a good scope for the Naval Architect, in designing vessels of this class, to produce an efficient, seaworthy boat, and at the same time, give a very handsome, speedy craft. There is considerable variation in the block and prismatic coefficients, probably greater than is met with in vessels of other types, and this is, no doubt, owing to the fact that with many passenger boats there are considerable restrictions in depth and draught, which are instrumental in producing, in order to give sufficient displacement, a very full hull, and, consequently, a high value for the coefficients. For ordinary purposes the block coefficient seldom exceeds 0.5, with a corresponding value of 0.55 to 0.6 for the prismatic coefficient, while on the other hand, it is inadvisable to go below a value of 0.35 for the block coefficient, except with a very small craft, working in upper reaches of rivers. While it is desirable to have the under-water body as fine as possible, it must, nevertheless, be borne in mind that the under-water body should be only as fine as is practicable.

The length-breadth and length-depth ratios vary considerably with this type of vessel, especially with craft working upon restricted waters. It will be noticed that the Board of Trade primarily base the passenger accommodation upon a function of the clear deck area, and since this is an important consideration with owners of excursion and such-like boats, it is not surprising to find, therefore, owners attempting to obtain the greatest deck area on a given length, and thus giving, as great a breadth as is consistent with sea-worthiness. If this be carried to excess, the draught must necessarily be small, else the displacement would be far too great, or the block coefficient ridiculously small, and the under-water body fine, and unstable. Fig. 87 gives the sheer draught of a Paddle Boat, which is a fair example of its class. The midship section, it will be noticed, is of good stable shape. The rise of floor is normal, and there is given a good turn of bilge. The forward waterlines show a fine, speedy boat, and while considerable flare is given to the sections in order to keep

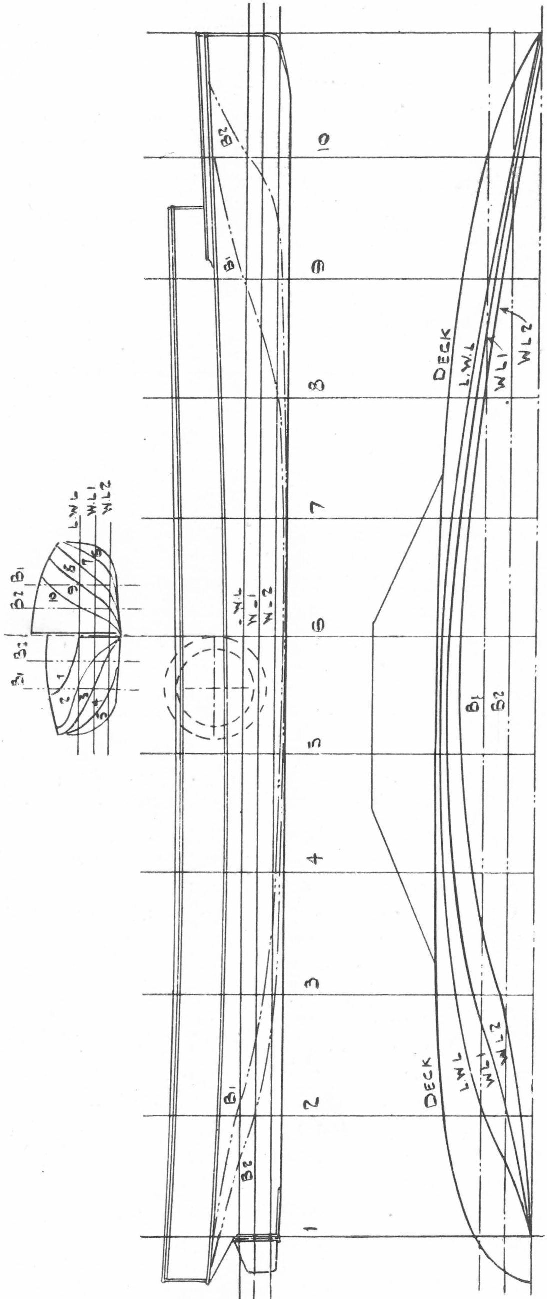


FIG. 87. SHEER DRAUGHT PADDLE BOAT.

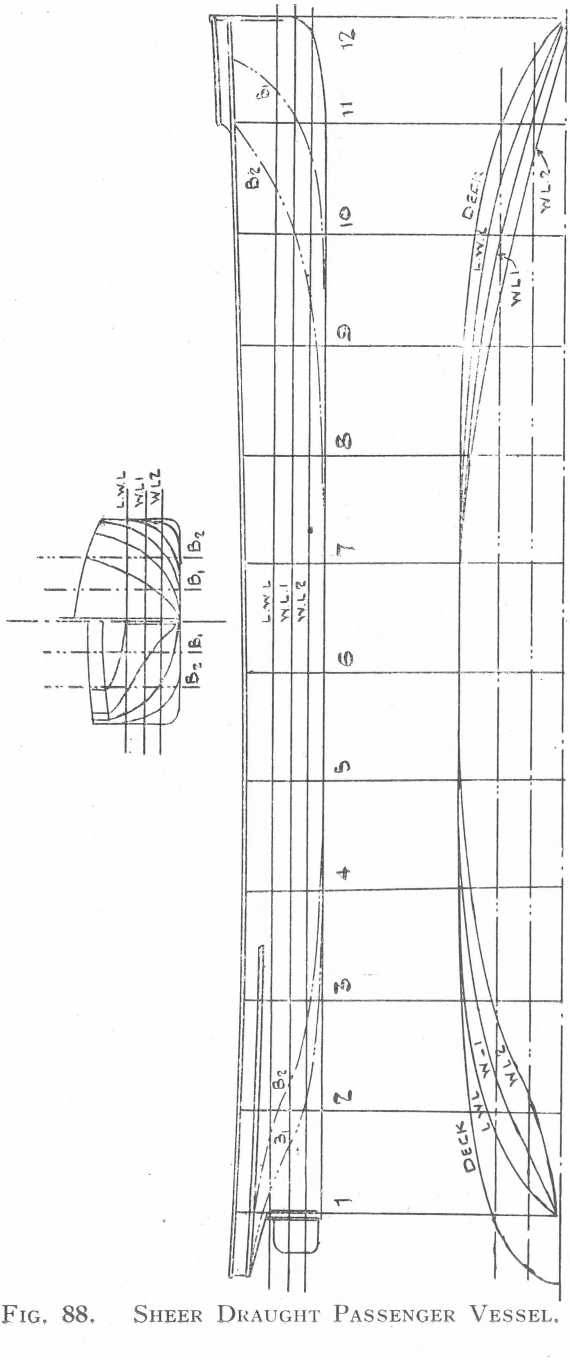


FIG. 88. SHEER DRAUGHT PASSENGER VESSEL.

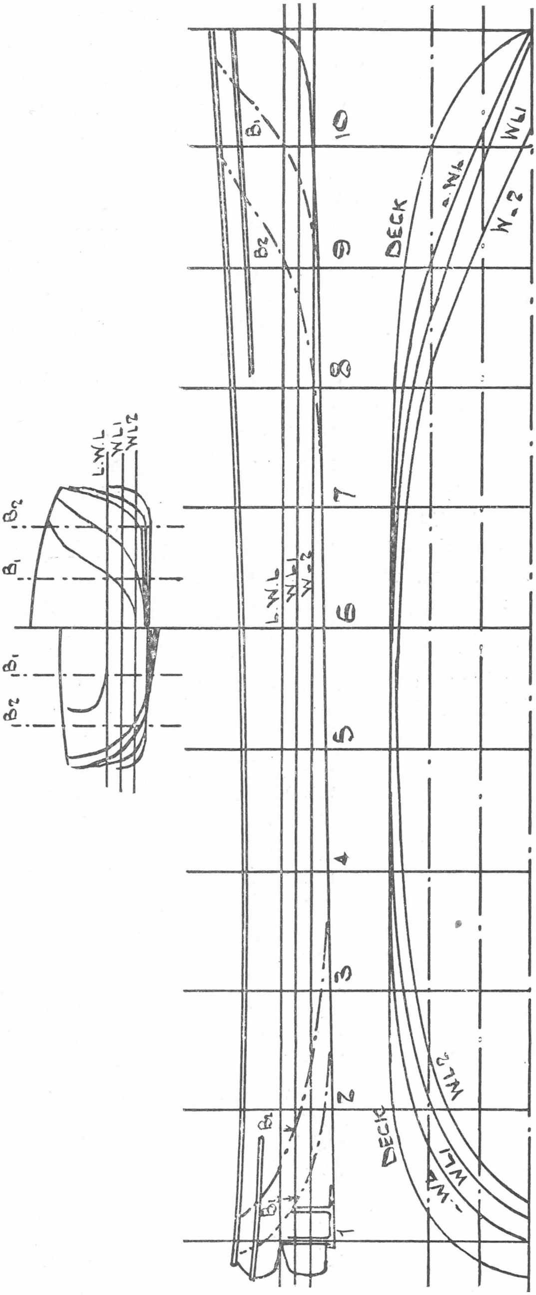


FIG. 89. SHEER DRAUGHT DUTCH PASSENGER VESSEL.

the forward deck dry, the tendency to the U shape at the shoulders, provides ample lifting power. The parallel middle body extends roughly the length of the boiler and engine space, and the after lines show a clean run, while the upper part of the sections flare out to provide lifting power and reserve of buoyancy to the after part.

A slightly different class of boat, the "Wyoming," is shown in Fig. 88. This vessel was designed for the Great American Lakes, and a study of the sheer draught may prove instructive. The fore body sections show a very full hull, and the U sections are continued to amidships without any variation. The midship section is full, and there is no rise of floor, and a very hard turn of bilge, probably owing to the fact that the vessel would frequently take the ground. The after lines show some relief, however, for a very fine run, with a sharp hollow in the water lines, show an inclination to a speedy vessel, with little resistance. The part of the after sections above water retain their fullness, probably because it was desirable to keep the deck area comparatively large aft.

The last design treated here is that of a Dutch passenger boat, Fig. 89, and while only measuring 75 feet overall, it is interesting to note that the boat is capable of carrying a total of 200 passengers, and installed with a 70 B.H.P. oil-engine, can speed at 9 knots when loaded. The forward lines while retaining the U section in way of the under water part of the forward length, have considerable flare introduced, which was considered necessary owing to the service for which the boat was intended. The midship section is full, the coefficient of fineness being about 0.94, and the fullness is continued for the whole of the after length, barely any hollow being introduced to the after sections to lead a clear stream of water to the propeller.

A point which presents itself in the consideration of the foregoing sheer draughts is the provision of sufficient stability. When it is remembered that the passengers are nearly always on deck in fine weather, and thus they tend to bring the centre of gravity relatively high, vertically, and while it is undesirable to have the righting lever too violent, for the comfort of the passengers, it is, nevertheless, important that ample stability should be provided. The metacentric height must be sufficiently moderate to make the vessel steady in a sea-way, and this can always be accomplished with normal proportioned vessels, and can be done consistently with other conditions being satisfied.

Sufficient freeboard and sheer are important, to provide ample strength of hull and a dry deck fore and aft. Where a boat has to pass under low bridges, it is often necessary to reduce these to a minimum, but with ordinary craft no difficulty should be experienced in this direction.

The approximate dimensions and weights of passenger vessels may be obtained from the curves, Figs. 90 and 91.

The arrangements of passenger vessels are many and varied. In some vessels, the main idea of the owners is the provision of seating accommodation, and where only short excursion trips are made, the cabins are only a provision for wet weather, and it is, therefore, unnecessary to provide any deck cabins, since sufficient space may always be found below. On the other hand, on some

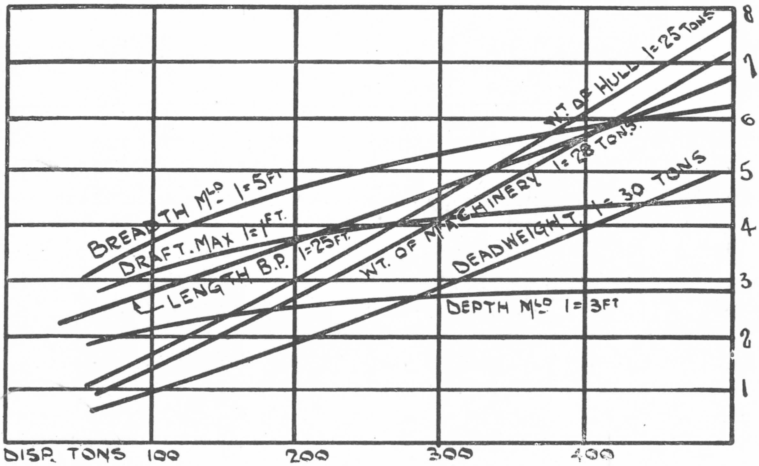


FIG. 90. CURVES OF DIMENSIONS, ETC. PADDLE BOATS.

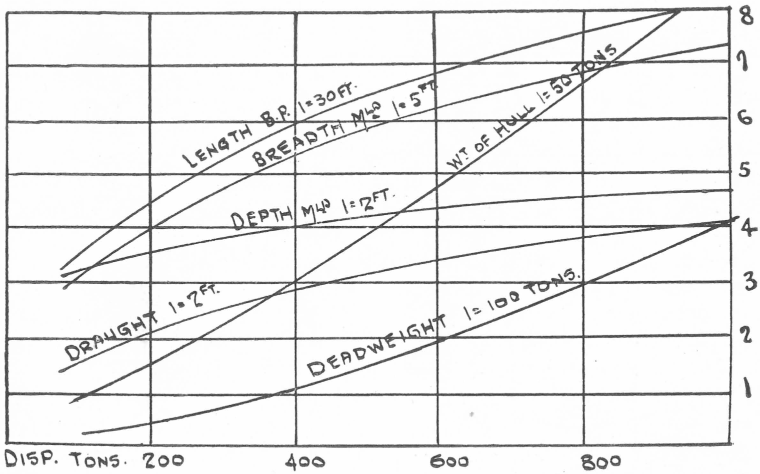


FIG. 91. CURVES OF DIMENSIONS, ETC. SCREW VESSELS.

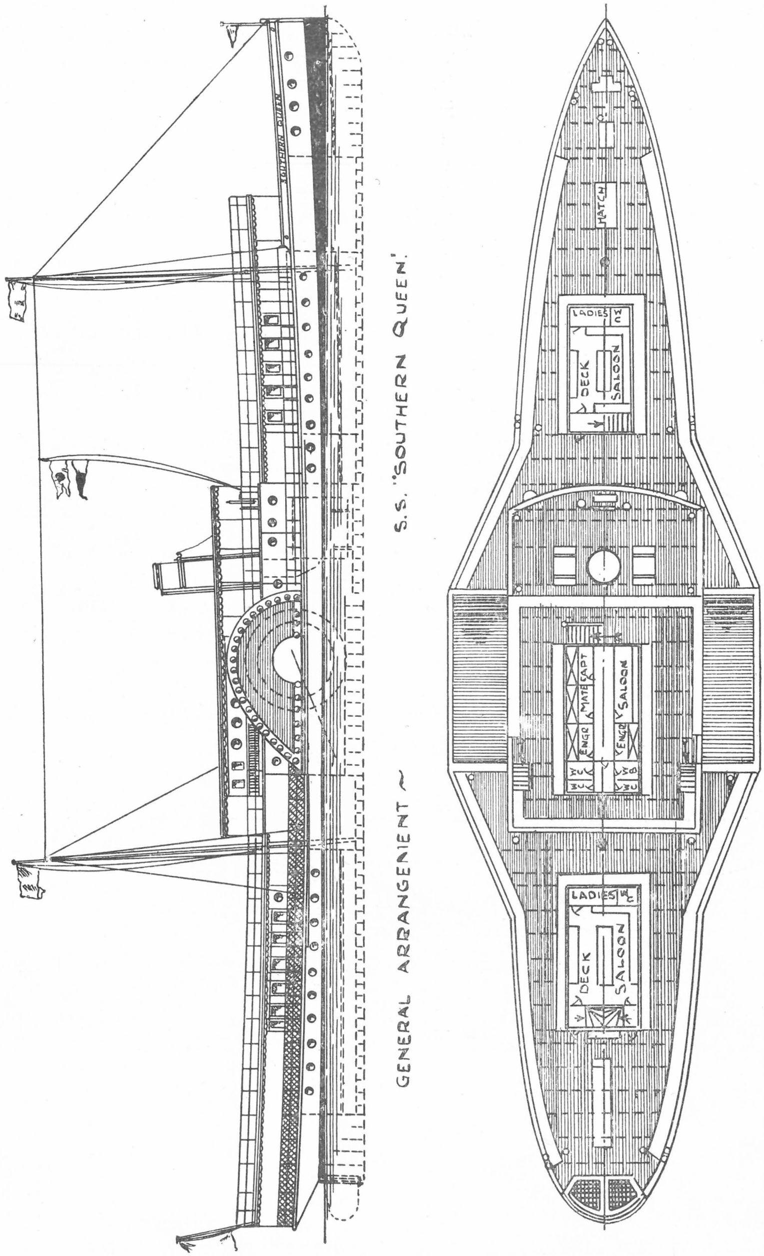


FIG. 92. GENERAL ARRANGEMENT PADDLE BOAT.

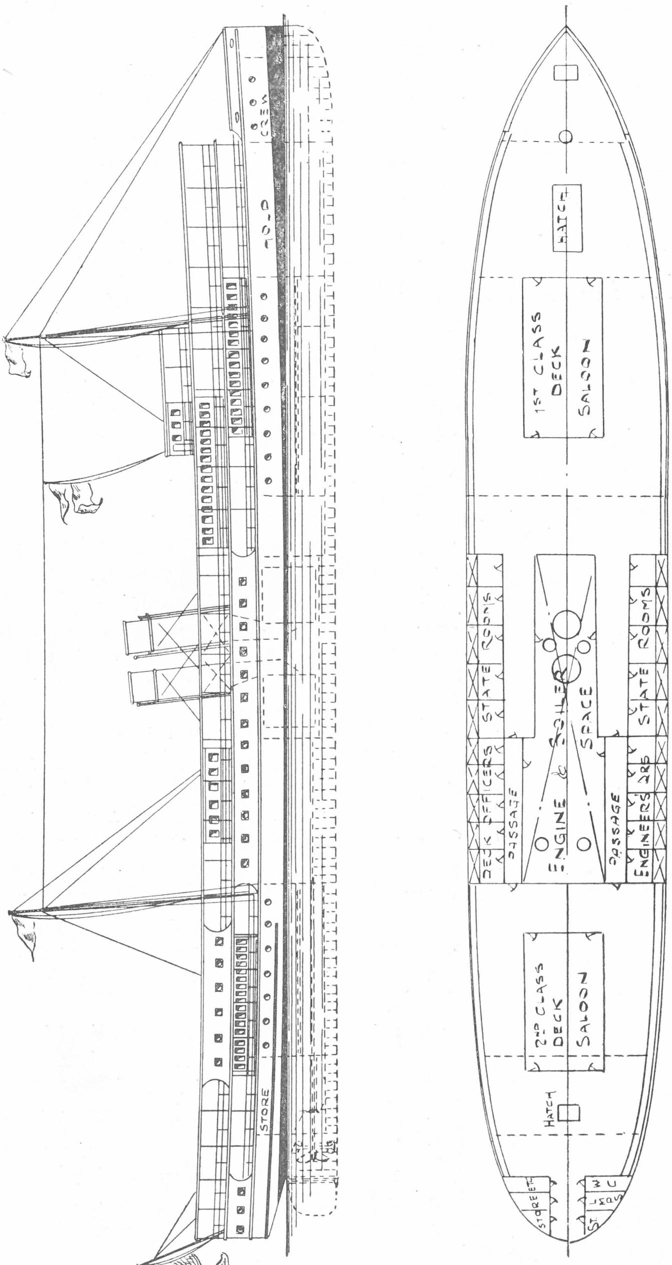


Fig. 93. General Arrangement Passenger Vessel.

services it may be necessary to provide, at least, some passenger sleeping accommodation, when the fitting of deck cabins becomes necessary. Fig. 92 shows the general arrangement of the "Southern Queen," a paddle vessel which was built in 1920 for South American waters. Her principal dimensions are :—

Length, between perpendiculars ...	192′ 0″
Breadth, moulded	26′ 0″
Breadth, over sponsons	44′ 3″
Depth, moulded	10′ 0″
Draught, loaded, aft	6′ 0″

The crew are quartered forward, abaft of which space is situated a small hold for carrying mails, baggage, etc. A fairly large dining room, fitted up with seats and tables, follows the hold, and this leads directly into the pantry and galley, which extends the full breadth of the vessel. The engine and boiler space occupies the amidship compartment, and a large saloon extends as far aft as practicable. On the main deck are two saloons, fitted with seats, and at the forward end of each is fitted a ladies' toilet. Above the engine and boiler casing are the officers' quarters, and at the forward end of the casing is situated a small steering bridge. An awning deck extends practically the full length of the vessel, and is fitted with battened seats for passenger accommodation. The "Wyoming," a somewhat larger boat, is shown by Fig. 93. The accommodation of this boat is different from the majority of English boats. Large deck saloons for 1st and 2nd class passengers are fitted to the main deck, while each side of the engine and boiler space is situated the officers' sleeping apartments and ten state rooms for passengers. A large dining saloon, together with galley, etc., is fitted on the awning deck, forward, while at the after end are twelve more state rooms. Seats are arranged around all decks, and the two saloons below deck at each end of the engine and boiler space are fitted up for passengers in case of wet or bad weather. The crew are quartered forward, and there is a small hold for general goods at the after end of the forecastle. The principal dimensions of this boat are :—

Length, between perpendiculars ...	273′ 0″
Breadth, moulded	48′ 0″
Depth, moulded	18′ 0″
Draught, aft	12′ 0″

The next vessel, Fig. 94, is of Dutch design, and was built for passenger service on the Zuider Zee. Her machinery, which consists of a marine oil engine of the semi-diesel type, is situated amidships, while directly forward is the crew space. A ladies' saloon is fitted in the fore peak, and at the after end of the vessel is a saloon for passengers, which leads out into a small cockpit. An English design for a boat of similar size compares very

favourably with this vessel. The "Swan," built for lake service, measures 85 feet overall length, is proportionately higher powered, and is capable of carrying more passengers. Fig. 95 gives the arrangement of this boat, from which all details of accommodation, etc., will be easily seen. A useful type of passenger vessel is illustrated by Fig. 96. This vessel, the "Waddenzee," is fitted with twin sets of Kromhout engines, developing each 40 B.H.P. The vessel was built for service in shallow water, and has propellers running in a tunnel stern. This illustration has been kindly supplied by Messrs. Perman and Co., Ltd.

Although it is usual practise to fit the bar or the side bar keel to vessels of this class, owing to the shape of the bottom, it is sometimes necessary, should the vessel often take the ground, to fit the flat plate keel, in which case the vessel has somewhat a flat bottom. While the scantlings of these vessels are, as a rule, on the light side, sight must not be lost of the fact that the strength of bottom and side are important considerations. Ample longitudinal stiffening should, therefore, be given, and it is not unusual to fit an intercostal plate keelson along the centre line of the vessel, and to attach it well to a centre keelson standing upon the tops of the floors, and made up of four angles and a rider plate. Sometimes in the smaller vessels, a bulb plate and two angles are fitted in lieu of the above, but it is important that the longitudinal rigidity should be preserved in all classes of construction. The garboard strakes should be proportionately heavy, and it is usual to fit a shoe-plate to the bar keel in order to take the wear and tear. If the width of the boat warrants the fitting of side keelsons, they are generally of double angles fitted back to back, on the tops of the floors, and, if necessary, an intercostal plate is fitted. The floors should be carried well round the turn of bilge, especially if the radius be large, and in the larger vessels the reverse frames must, of course, be continued up to the frame heads, although in small vessels it is common to stop them at the floors, or even to omit them, making the necessary compensation by giving an $1\frac{1}{2}$ or 2ins. flange to the top of each floor.

When a vessel is frequently coming alongside a pier or jetty, there is of necessity considerable wear and tear of the side plating, and it is of importance that the sides should be well stiffened, and the plating of substantial thickness. Single or double stringer angles should be fitted on the face of the reverse frames, and where the cabin sole beams, together with their stringer plate and angles, are fitted, care should be taken that the spacing of the stringers be such that the maximum strength is obtained by their combination. Fenders are always run along the sides to take the rub, etc., and these should be of double angles and oak, but it is preferred by some to fit only the half-round or convex iron bars in exposed areas, but these do not add to the appearance of

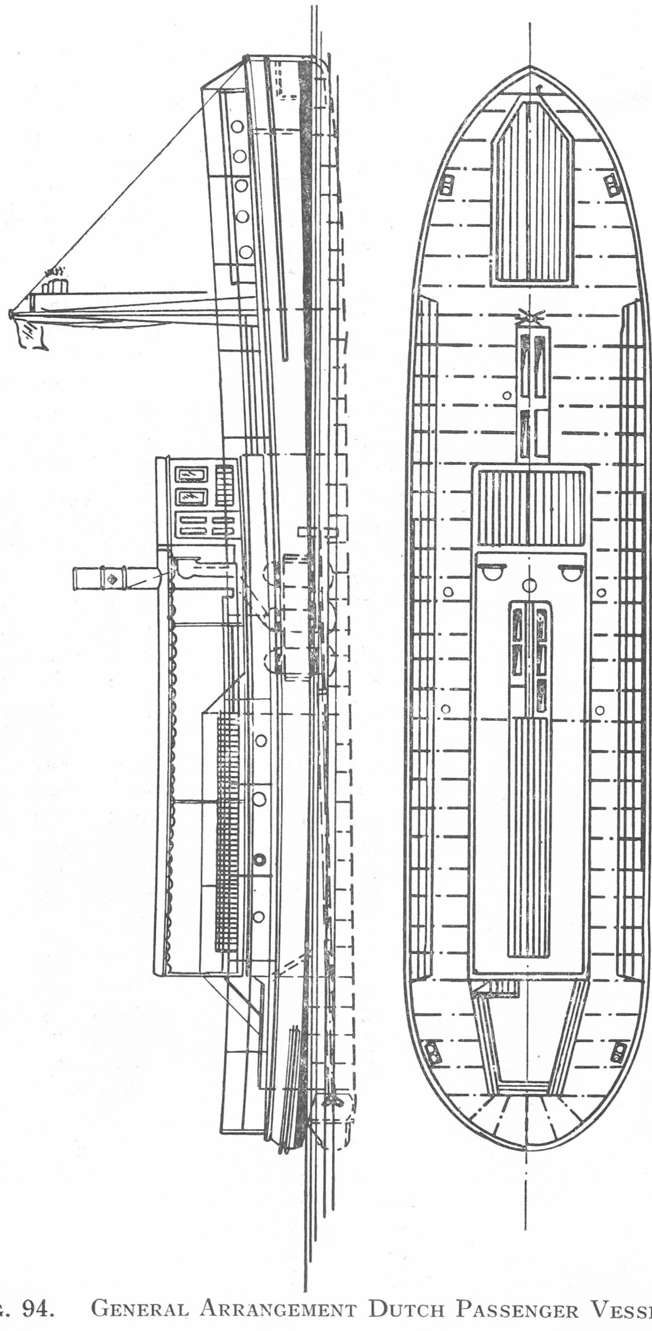


FIG. 94. GENERAL ARRANGEMENT DUTCH PASSENGER VESSEL.

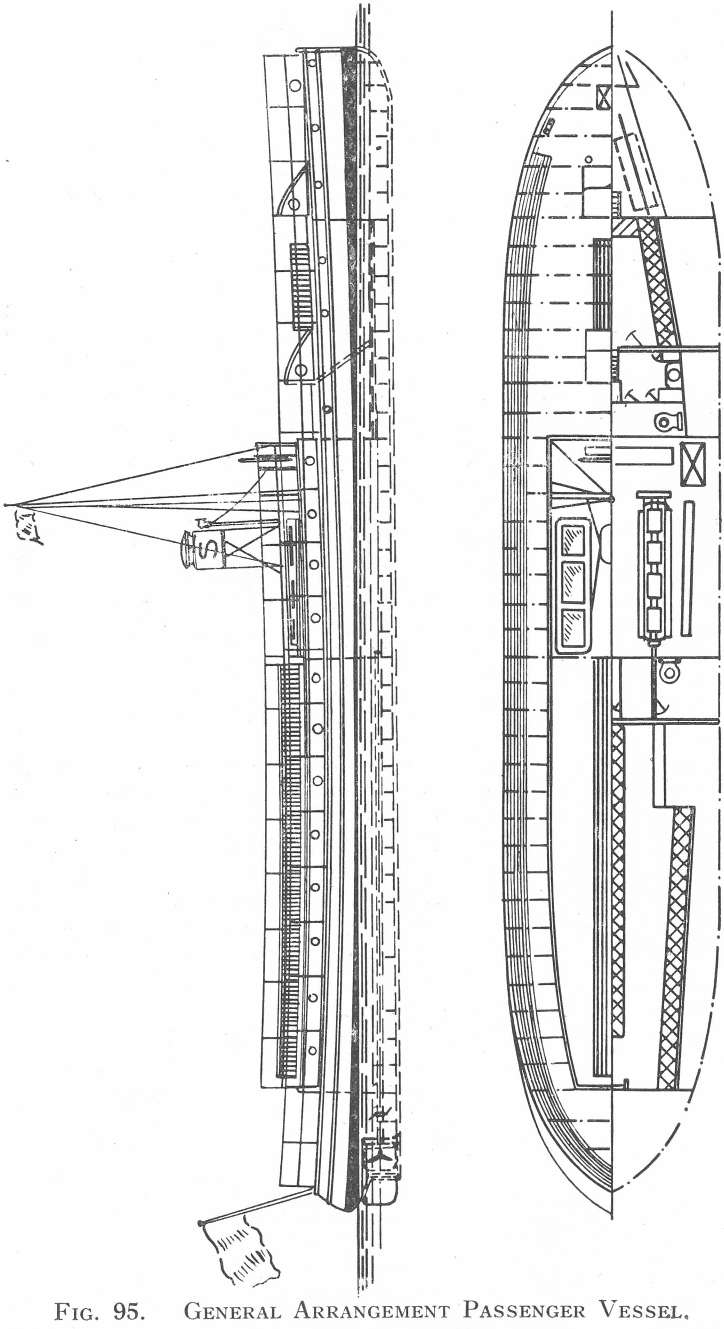


FIG. 95. GENERAL ARRANGEMENT PASSENGER VESSEL.

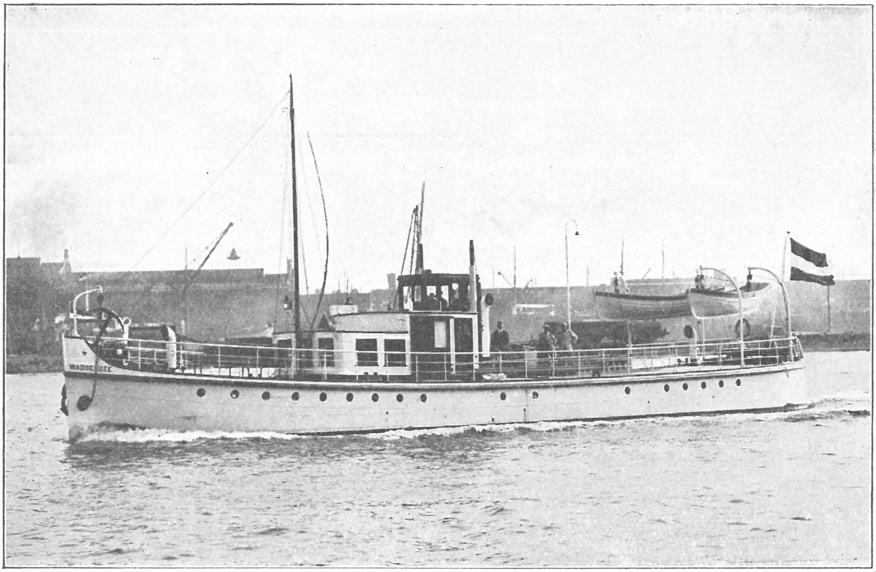


FIG. 96.

the craft, which is, to a certain extent, of advertising value to the owner.

In some of the smaller vessels it is usual to fit the deck stringer angle under the deck, and joggle the frames over them to take the beams. Although by this method clearer deck space is obtained, and a neater fitting of the covering board, etc., it must be remembered that to an extent the value of the stringer is lost, and there is less efficient connection to the beams and stringer plate, and the difficulty of fitting, and the extra joggling of the frames produces a more expensive structure than would otherwise be. Another method, and perhaps cheaper, of fitting the stringer angle when it is required to extend the covering board beyond the side of the vessel in the form of a rubbing strake, is to fit the inner face of the deck stringer bar on the top face of the deck stringer plate, thus while the other flange of the angle can pass over the top of the frames, providing the frames are stopped short at about $2\frac{1}{2}$ins. from the underside of the deck, efficient connection can be easily made with the beams without any joggling. The efficient connection of the beams with the side of the vessel is very important, especially where the length-depth ratio indirectly gives rise to considerable racking strains at the joints. In order to preserve the longitudinal strength of the vessel, a centre deck tie-plate is fitted on the face of the beams, and this should be

continuous as far forward and aft as practicable. Wood decks are usually fitted, generally of hard wood, although larch and pine are often used in cheaper boats.

The beams are usually of angle, bulb-angle or tee-bulb bars, on alternate frames, except under water-tight flats. At everv break of deck, each end of the engine and boiler openings, and at the end of saloons, care must be taken to see that sufficient compensation is made. In order to tie properly the floors and beams, a malleable steel or iron pillar should be fitted as near as practicable to the centre line of the vessel. In way of the saloons, boiler and engine rooms, where pillaring is difficult, some compensation must be made in the way of girders. Where there is more than one deck, the pillars should be one above the other in order that they form continuous ties from the deck to the floors.

The Board of Trade lay much stress upon the fitting of sufficient water-tight bulkheads. Although no special rules are laid down, they treat the complete subdivision of the ship with great care. A water-tight collision bulkhead and an after stern-tube bulkhead must be fitted, and with the vessels plying in smooth or partially smooth water, modifications and deductions are allowed. In any case, the provision of bulkheads is important in the provision of the transverse strength of the vessel, and wherever possible it is desirable that they should be fitted. If there is a large breadth to the bulkhead, care must be taken to see that the plating is efficiently stiffened by angles, etc., and if there is any stoppage of the longitudinal members of the construction, great care must be taken to see that the strength is continued, by the fitting of deep bracket plates and angles. If possible, it is best that no door be fitted to the water-tight bulkheads, but where it is necessary to have them, it is important they should be of such design that they can be opened and closed efficiently and expeditiously, and should be capable of being worked from the upper deck, or from some point situated well above the load water line. If the floors at the bulkhead have man-holes or any openings, water-tight covers must be fitted.

All superstructures, such as awning decks, etc., must be strongly and effectively built, and well connected to the hull. Light awning decks are usually laid in pine or larch, or if the vessel be for tropical service, teak. Angle beams at alternate frames are usually adopted, and are well tied together at the sides by a vertical and horizontal stringer plate of suitable width and thickness, and connected together by an angle bar. Tie plates are fitted should be carried the full and length of the deck, tapering suitably at each end, to add to the longitudinal strength of the deck. Pillars are at each end of the beam, and one should be as near the centre line as practicable. They

should be of malleable steel or iron, and should have solid welded heads and heels. Runner angles are run under the beams, and attached to them by angle lugs, for connection of the pillars to the beams, this method giving greater continuity of strength to the structure. If there be a great breadth of deck and but little support from deck houses below, diagonal tie plates, composed of a flat plate stiffened by angle bars, must be fitted in order to prevent any working of the structure should the vessel be in a seaway or be under a strong broadside wind. If two awning decks

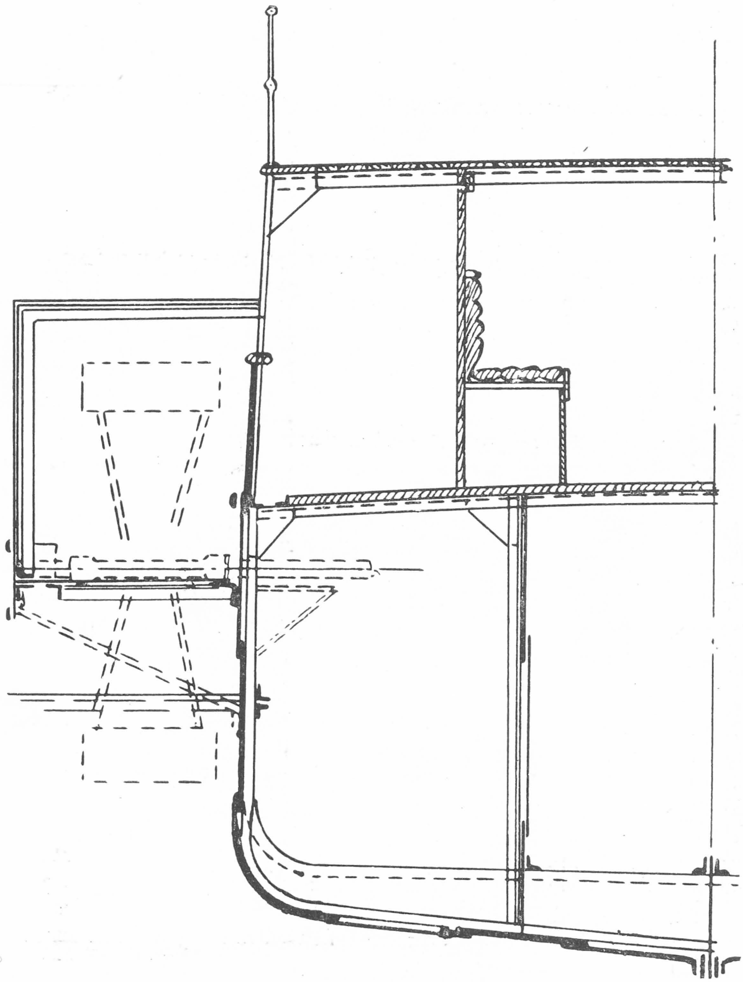


FIG. 97. MIDSHIP SECTION PADDLE BOAT.

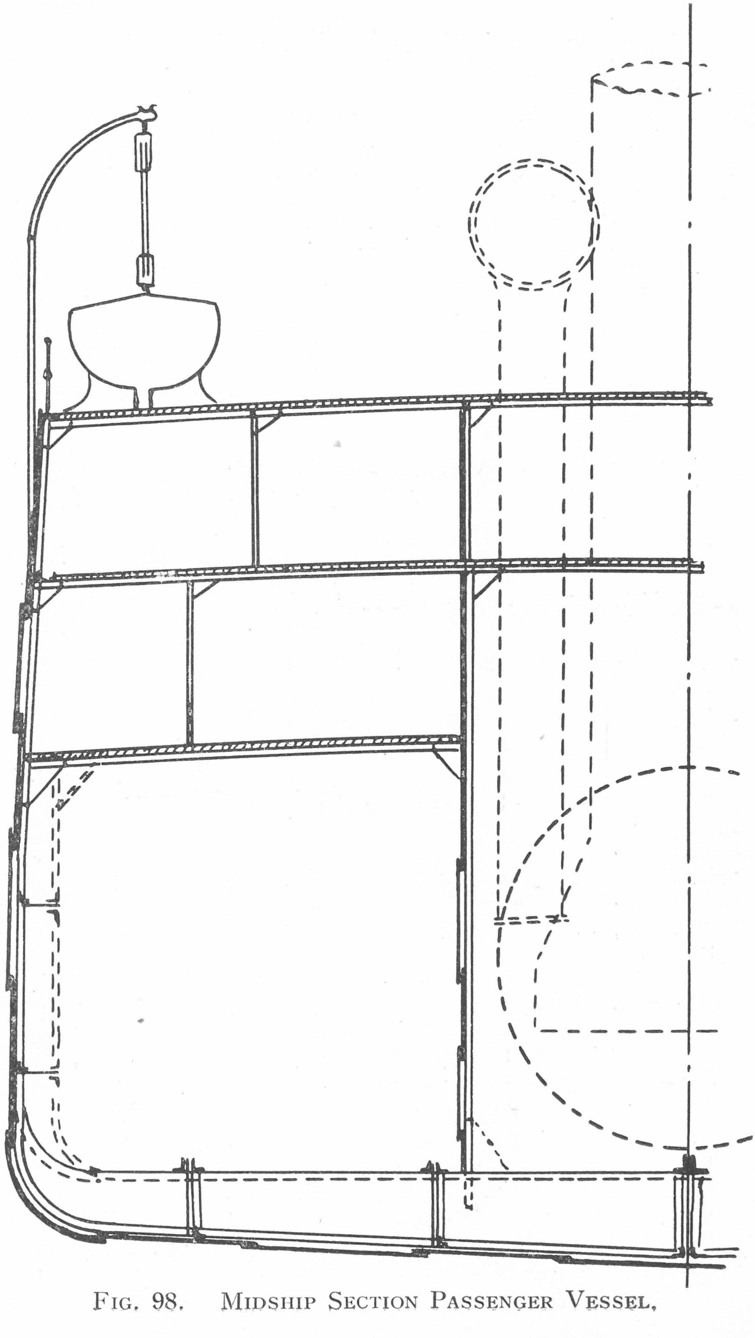


FIG. 98. MIDSHIP SECTION PASSENGER VESSEL.

be fitted, the diagonal tie-plates should be continuous down to the main deck, in order to preserve the rigidity and continuity of strength of the structure.

Fig. 97 gives the midship section of a paddle boat, and Fig. 98 is the midship section of the "Wyoming," and the details of the construction may be easily seen. The mid-ship section of the Dutch passenger vessel is given by Fig. 99. It will be noticed that with this vessel the stringer is just above the cabin sole beams, and is composed of a wide plate and two angles. The

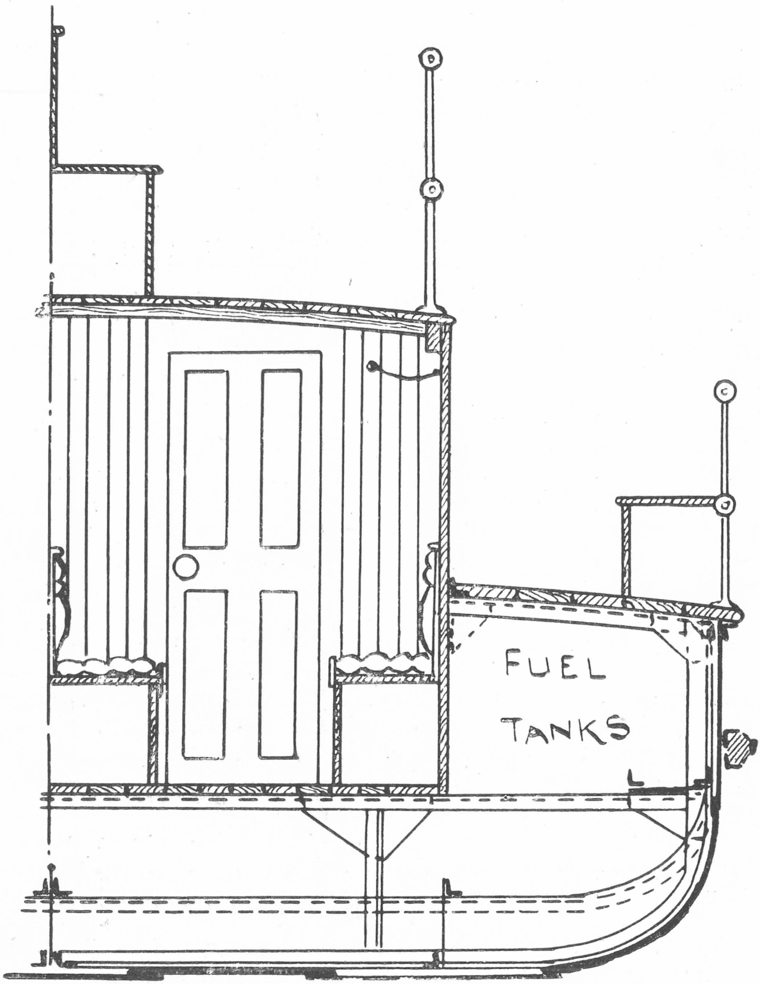


FIG. 99. MIDSHIP SECTION DUTCH PASSENGER VESSEL.

beams, which are supported by four angle pillars, attached to the beams by plate brackets, are well connected to the frames by deep plate brackets. No beams are fitted for the length of the wooden house, two angle bars being sufficient stiffening for the narrow deck stringer plate.

The deck arrangements vary considerably with different boats, but in the larger of the passenger vessels, where the anchors are heavy, steam windlasses are fitted, although with most of the smaller craft, hand windlasses are sufficient. In some smaller boats it is found advisable to fit winch-top capstans, which can be worked with either the handle or the bars, and several good makes of these are on the market. Full equipment of bow and stern anchors is necessary, but these are not generally of large size, the largest of the boats having the Bower of 28 hundredweights, and the stream and kedge of 9 and 4 hundredweights each, respectively, and with a smaller 100-ton Y.M. vessel two bower anchors of 2 hundredweights each, one spare anchor of $1\frac{1}{2}$ hundredweights, and a third kedge anchor of about 90 lbs. are sufficient.

Where cargo is carried, it is usual to fit either a steam or hand winch, for the working of the cargo, and it is usually arranged that the foremast carries a derrick, so that if needs be, the cargo can be swung out independently of the unloading appliances ashore. Where motors are installed, a motor winch is adopted, and it is preferable if this type be installed, that the motor be directly coupled to the winch, as then a wood casing can be fitted, and the whole machinery made as compact as possible. Plans have been adopted whereby the winch can be worked by the main engines, but the inefficiency of this method, especially where the engines are some distance from the winch, is sufficient to warrant the installation of a separate motor.

It is seldom necessary to fit any steam steering machinery, since an ordinary gear, with cables and wire leads, and suitable buffers are sufficient. In some vessels where there are bulwark rails, the leads are taken aft under the deck, suitable wood casings being fitted. The inadvisability of this plan is apparent, for should the wire or cable break, it is a difficulty to find the point of fracture, and repairs, or refitting, would cause considerable and unnessary trouble. In all cases it is advisable to fit such leads that in case of accidents, access to them may be as easy as possible.

Suitable bollards, fairleads, etc., complete the deck fittings.

The powering of passenger vessels is a problem which varies almost with each craft. Many points such as conditions of service, must be taken into consideration in determining the speed at which it is intended to drive the vessel. While it is desirable, from the owner's point of view, to have as great a speed as possible with the smallest amount of machinery space,

there are various River Conservancy Boards which make statutory rules in reference to maximum speeds, and where the river is narrow, and the banks are unprotected, the speed of the vessel must necessarily be low. On the other hand, vessels plying on short excursions to sea, are under no such obligations, and the amount of space devoted to machinery is a matter of compromise between speed and passenger accommodation. This may seem a strange way of solving or attempting to solve the problem, but nevertheless, the ultimate speed of the vessel is governed by the space allotted to the propelling machinery. Figs. 100 and 101 give respectively the B.H.P. and the I.H.P. These are based upon the formula :—

$$\text{I.H.P.} = \frac{75 \times \sqrt{W \times L} \times V^3}{100{,}000}$$

where W = displacement of vessel, in tons,
L = length of vessel, in feet, between perpendiculars
V = speed of vessel in knots.

Although the Admiralty coefficient formula is often used, the above gives reliable results for speeds up to 12 knots. The constant 75, may vary between 62 for very fine ships to 83 for full vessels with a large length-breadth ratio. A somewhat more cumbersome formula for computing speed and power is :—

$$\text{I.H.P.} = \frac{5(L \times D \times 1.7) + (L \times B \times C_b) \times V^3}{100{,}000}$$

where D = mean draught of vessel, in feet.
B = the breadth of the vessel, moulded, in feet,
C_b = the block coefficient of vessel,

the other symbols remaining as above. There is little difference between the two formulæ, the expression for the wetted surface simply being in different terms. The latter formula is used extensively in American yards, and apparently gives good results for low speeds. Where oil-engines are installed, the necessary allowance must be made if B.H.P. is substituted for the Indicated Horse Power, and although many allow from 10 to 15 per cent. on the total figure arrived at, it must be borne in mind that the revolutions of the engine must be taken into account, since with the high speed engine in the somewhat slower boat, and the comparative inefficiency of the propeller, due to slip, etc., greater power may be necessary. It is, therefore, necessary to acquaint

oneself with the engine it is proposed to instal, before taking any definite steps in the determination of the speed and power.

The fixed paddle wheel, *i.e.*, with the fixed floats, which was formerly introduced, is now seldom seen in this country, and where side wheels are used, they are generally of the feathering float type. These wheels, the invention of Elijah Galloway, were first used in 1830, and have come down unchanged in principle, to the present time. The arrangement of the floats is such that they enter and leave the water without undue disturbance and shock, this is accomplished by giving the floats when entering, leaving, and during their passage through the water, the same angular position to the vertical that they would have should they be fixed floats of a wheel of considerably greater diameter. What the diameter of the feathering float wheel should be is a matter of geometrical construction, which must take full consideration of the R.P.M., the fraction of slip, the speed of the vessel, and the relative diameters of the wheels. Should for any reason, the sectional area of the projected stream of water be restricted or reduced, there must of necessity be an equivalent increase of the rate of flow, so that the final result may be the same. The increase of the slip, therefore, can only be made in the speed of the wheel, in so far that the speed of the vessel is kept constant, and therefore, the speed of the floats must be increased in some proportion, as the area of the floats is reduced, and since the area of the floats varies inversely as the square of the speed, it is necessary with the modern high-speed steam engine, to have the floats, and therefore, the diameter of the wheel, as small as possible. Since, generally speaking, the smaller the R.P.M. of the engines, the greater the space they occupy, and bearing in mind that it is most desirable for the engines to occupy as little space as possible, it is not surprising to find with the higher speed engine, and the smaller diameter wheel, a comparatively greater slip than was usually to be found with the older fashioned boats. The value of slip, therefore, may be often found to exceed 27 per cent. although the general figure is between 15 and 25 per cent.

The diameter of the wheel, it has been said, varies according to the revolutions of the engines, the speed of the vessel, and the amount of slip.

Thus if D = diameter of the wheel at float centres, *i.e.*, the effective diameter, in feet,

A = area of one float in square feet.

V = speed of ship in knots

S = velocity of float centres in feet per second

$$= 2\pi D \times \frac{\text{R.P.M.}}{60}$$

R = resistance of ship in pounds

f = fraction the slip is of S—that is $\dfrac{S - v}{S}$

v = velocity of ship in feet per second

$$= \frac{V \times 6080}{60 \times 60} = 1.689\ V.$$

R.P.M. = revolutions of wheel per minute.

Then, the stream of water projected by each wheel = $A \times S \times 64$ lbs.

The mass of water $\dfrac{A \times S \times 64}{32} = 2\ A \times S.$

The net work done (thrust × speed of ship in feet per minute)

$$= 2A \times S(S - v)60v$$
$$= 120A \times S(S - v)v$$

The speed of the wheel, $S = \dfrac{\pi\ D \times R.P.M.}{60}$, and by adding the slip we get $D = \dfrac{19 \times S}{R.P.M.}$

If the stream of water projected by the float be equal to the area of the float, and if we may presume that the apparent slip be the real slip, it is an easy matter to find the area of the floats, for if the quantity of water projected per second be

$$\frac{A \times \pi\ D \times R.P.M.}{60} \text{ cubic feet}$$

and the acceleration be taken as $fS = \dfrac{f \times \pi\ D \times R.P.M.}{60}$

Then, mass of water $= \dfrac{A \times \pi\ D \times R.P.M.}{60} \times \dfrac{64}{32} =$

$$\frac{A \times \pi\ D \times R.P.M.}{30}$$

$$\text{Thrust} = \frac{A \times \pi\ D \times R.P.M.}{30} \times \frac{f \times \pi\ D \times R.P.M}{60}$$

$$= \frac{Af}{1800}(\pi D \times R.P.M.)^2$$

$$\text{or } A = \frac{\text{thrust} \times 1800}{f(\pi D \times R.P.M.)^2} = \frac{\text{thrust}}{(D \times R.P.M.)^2} \times \frac{182}{f}$$

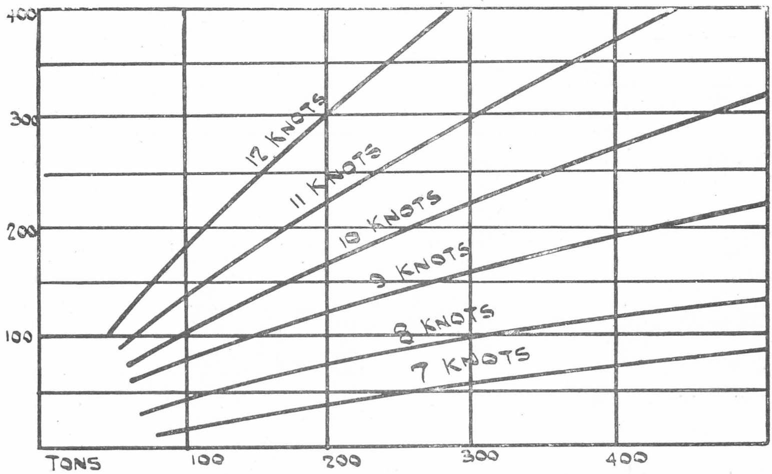


FIG. 100. SPEED AND POWER CURVES (B.H.P.).

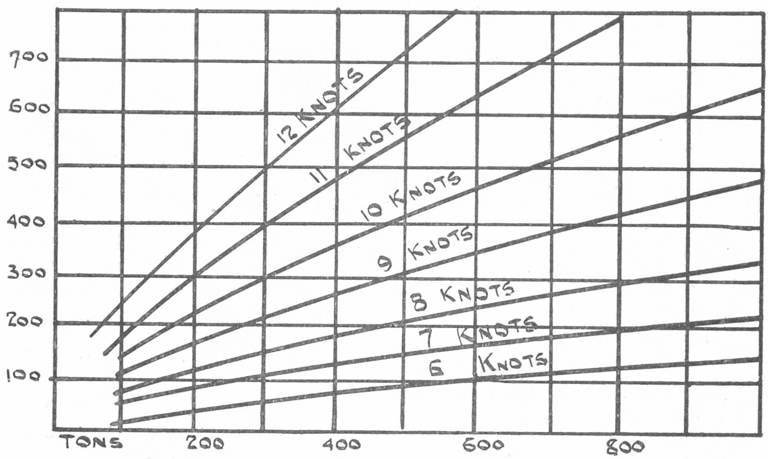


FIG. 101. SPEED AND POWER CURVES (I.H.P.).

This thrust, it must be noted, is due to the effort of one wheel, so that should the thrust be calculated from the ship resistance, only half the value should be used in the above equation if two wheels are fitted.

The following formula is established from above—

$$\text{Area of one feathering float} = \frac{\text{I.H.P.}}{f - f^2} \times \left(\frac{C}{D \times \text{R.P.M.}} \right)^3$$

The value of C is dependent upon the efficiency of the engine and with two wheels driven by engines with an efficiency of 0.6 and where the I.H.P. is the gross power developed, its value may be taken as between 82 and 84. As the efficiency increases, however, the value of C also increases, so that with engines of 0.66 efficiency, the value would be increased to about 85 or 86.

It is of interest to note that where a single wheel is fitted at the stern, the value of C is 109.

It was usual to fit one float to every foot of diameter of wheel in the older radial wheels, but with modern practice it is usual to fit the least number possible, consistent with efficiency, etc. The number of floats is given by dividing the diameter of the wheel, in feet, plus two, by two, as given by $N = \frac{D + 2}{2}$, but with small diameter wheels it is sometimes necessary to give somewhat more floats than is given by the formula.

The proportion of floats has received considerable attention within recent years when it has been necessary to fit wheels to shallow draught vessels. The immersion of the wheel must always be greater with sea-going boats, but those plying in partially smooth water should have, to obtain the greatest efficiency of float, an immersion of the upper edge of the lowest float below the load water line of at least half the breadth of the float. In river craft where the water is generally smooth, an immersion of only one quarter the breadth is sufficient, and with very light draught it is common to have an immersion of only one-eighth, but it is advisable to have, within reason, the greatest immersion for the floats possible. This, therefore, has some effect upon the proportion of the floats, but for ordinary purposes, a proportion of length of float to breadth of 2.6 : 3 for floats of the feathering type, while a proportion of 4 :5 is usual for the fixed radial wheel float.

As mentioned previously, the wheel has a distinct advantage, both theoretical and practical, over the screw, and in rough and windy weather, or when frequent calls are to be made at piers, etc., the greater manœuvring power is a considerable advantage over the screw, also when working in shallow waters, the wheel shows great advantage in efficiency over the tunnel screw. On the other

hand, however, the paddle boxes are heavy and cumbersome, exposed to damage, and they do not in any way assist in the stability of the boat. The machinery, too, occupies a larger amount of space, and is much heavier than the usual compound condensing or the triple expansion sets in screw boats.

In the design of the screw propeller, there are not many differences from the ordinary types, since the conditions are compatible. Except with the propeller driven by oil-engines, the blade of the propeller is usually leaf-shaped, and sometimes a little set-back is given to the blade, although the slip per cent. is by no means excessive. To obtain the highest efficiency, the propellers should be of bronze, or such metal, and the cutting edge should be as fine as practicable. A large projected area of blade and a large pitch-diameter ratio is unnecessary, although several boats recently have had disproportioned propellers fitted, but with indifferent results. Because there is a fine under water body, with very fine lines aft, there is no necessity to fit abnormal propellers, the best results having been obtained with normal proportioned screws. It is no doubt an advantage to fit twin-screws wherever possible, but with a very light draught vessel, where the upper tips of the propeller are not submerged, when at rest, better results seem to have been obtained with the single screw.

Chapter 10.

FERRY BOATS.

It was, no doubt, to ferry service that the earliest steam vessels were put, and the call for this class of vessel has by no means relaxed during recent years. The "Clermont," Robert Fulton's steamboat which was built on the Hudson in 1807, may well claim to be the first river and ferry boat. Her eventful history needs no elaboration here since the events of her trial trip along the Hudson River is fully recorded in the Annals of Shipbuilding and Marine Engineering. The "Philadelphia," built in 1813, was a more successful vessel than the "Clermont," and performed her duties satisfactorily for several years. It is interesting to note that while these very early vessels were built in America, the home of ferry craft is to the present day the Great Lakes and rivers of that country. Great advancements were made during the latter part of last century, until large ferry boats, capable of conveying several trains, rolling stock, motors and waggons, passengers, etc., were by no means exceptions. Some years previous to the late war a large vessel—the "Drottning Victoria"—was built for ferry service from Germany across the Baltic to Sweden. This remarkable vessel, measuring 370 feet in length, was capable of accommodating eight bogie railway carriages, each of 72 feet in

length, on two tracks on the main deck, besides a considerable number of passengers. Soon after the launch of this vessel followed two very remarkable Railway Ferry and Ice-breaking Boats, the "Ermak" and the "Baikal," built by Messrs. Sir. W. G. Armstrong, Whitworth & Co., Ltd., for service on Lake Baikal, in Central Asia. The "Volga," a similar vessel built by the same firm, is a notable example of the train ferry. This vessel had a large hoist at one end, in order to raise the engine and carriages since there was a difference in the height of the banks; two trucks or one carriage could be hoisted at one time by this method. Although differing considerably from the foregoing vessels, the "Leonard," a twin-screw train ferry built by Messrs. Cammel Laird & Co., for conveying traffic across the St. Lawrence to Quebec, is a very notable example of a river ferry boat. Instead of the "ship-shape" hull, the main body of this vessel is flat and pontoon shaped, with a comparatively small depth and freeboard. The main deck is left entirely clear, except, of course, for the train rails, and this, therefore, needs a special arrangement of the boilers in order that the funnels, of which there are four, can be fitted as near the side of the vessel as possible. A large superstructure of steel, continued all forward and aft, carries the bridge and chart room at the forward end.

Ferry boats fall into two distinct classes, which very materially differ both in design and construction. As may be expected, a vessel employed on, say, cross channel work, where rough and cross seas may be experienced, needs a totally different design from vessels plying solely on rivers or lakes. Again the latter class may be further divided into vessels employed in partially smooth waters, *i.e.*, on estuaries and lakes, and on smooth waters, *i.e.*, on sheltered waters and the upper reaches of rivers. Therefore for the purposes of this chapter they may be divided up as follows :—

Type I.—Vessels plying on open water and on cross-channel service.

Type II.—Vessels employed in estuary and large lake service.

Type III.—Vessels plying on smooth and sheltered waters.

Vessels coming under Type I. should, wherever possible, have a good "ship-shaped" hull. A good sheer is necessary but is seldom given owing to the fact that a flat deck is preferable when rails for trains are to be fitted. The flat stem and full U sections of the forward body do in no wise help to keep the deck dry, and while it is important that a forward deck should be kept reasonably dry, especially where there is a well for the accommodation of trains or motors, etc., it is nevertheless equally important that sufficient buoyancy be provided at the ends. Where it is necessary to fit the train rails, this cannot always be done unless suitable arrangements are made at the stern for the running of carriages on and off the ship; the latter arrangement is, in the long run, far

better than fitting the excessively full bows, and many of the cross channel ferry vessels which ran from Richborough and Southampton to the North French coast had the necessary arrangements at the stern for running off the carriages and guns, the forward end of the vessel having the usual bar stem. The forward sections, then, should be of a combination of the V and U form, gradually merging into a full, stable midship section. The latter should have a fair rise of floor, with a good radius of bilge, but on no account should a tumble home be given to the midship sections unless there are more than two decks above the main deck.

When a flat stern is given for transporting trains, etc., ashore, the sections more or less modify the type of after lines, which would be somewhat full and round. If on the other hand, the ordinary elliptical stern is fitted, the after lines while being fine to give a lead to the screws, are nevertheless filled out as they progress above the load water line so that sufficient reserve of buoyancy is provided; this will be understood, when it is mentioned that the main deck is generally kept as clear as possible fore and aft, and therefore the reserve of buoyancy afforded by raised quarter decks, is lost.

Vessels coming under Types II. and III. do not require so much consideration as regards sea worthiness, and little difficulty is experienced in the provision of a reasonably dry deck, and suitable shape of under-water body.

Most of the Passenger ferry vessels have a fine appearance and there is much scope for a Naval Architect to produce a smart, handsome craft. The weight of the hull is generally light, and the passengers, when cargo is not carried, do not make a great increase in the displacement, therefore a hull, with a small block co-efficient, can be designed without many restrictions. American ferry boats engaged in work coming under Type II. are often of V section all fore and aft, and to a certain extent this section simplifies and cheapens the construction, especially if it be of wood. A modified section is the "double V," *i.e.*, with an excessive rise of floor and out-raking sides, and this, while also cheap, gives a rather more stable section. When the usual type of lines are required, the midship section has generally a large rise of floor, and a very large radius of bilge, except when the vessel has to take the ground frequently. The forward and after lines are particularly fiine, and when cargo is not to be carried, the forward sections continue a V section for some considerable distance abaft the stem.

Should there be any restriction upon depth or draught, there must be a corresponding alteration in the character of the lines, and it is not uncommon, especially when heavy waggons or rolling stock are to be carried, for the hull to be pontoon shaped, *i.e.*, to have flat bow and stern and full U sections continued all fore and aft. These are very unsightly vessels, especially when there is a great depth and freeboard in order that the main deck will be

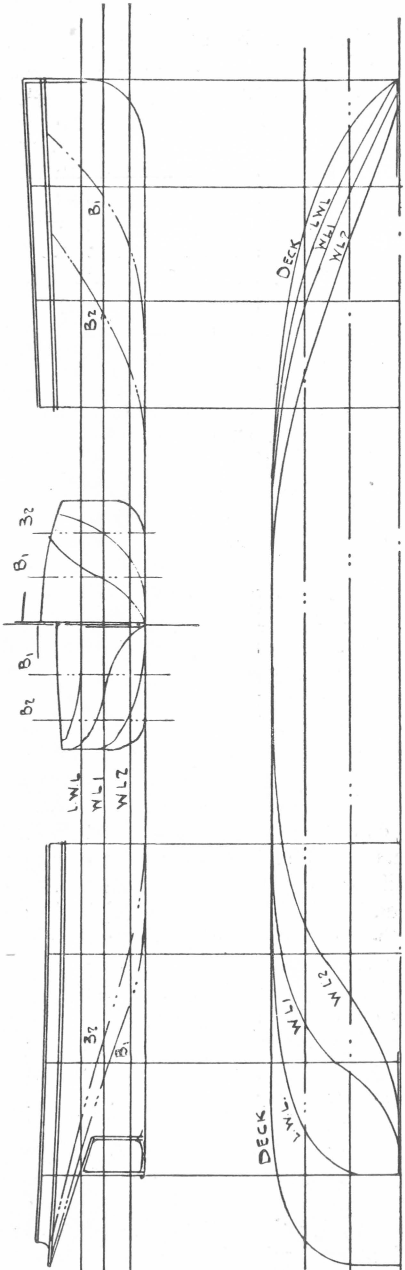


FIG. 102. SHEER DRAUGHT FERRY BOAT.

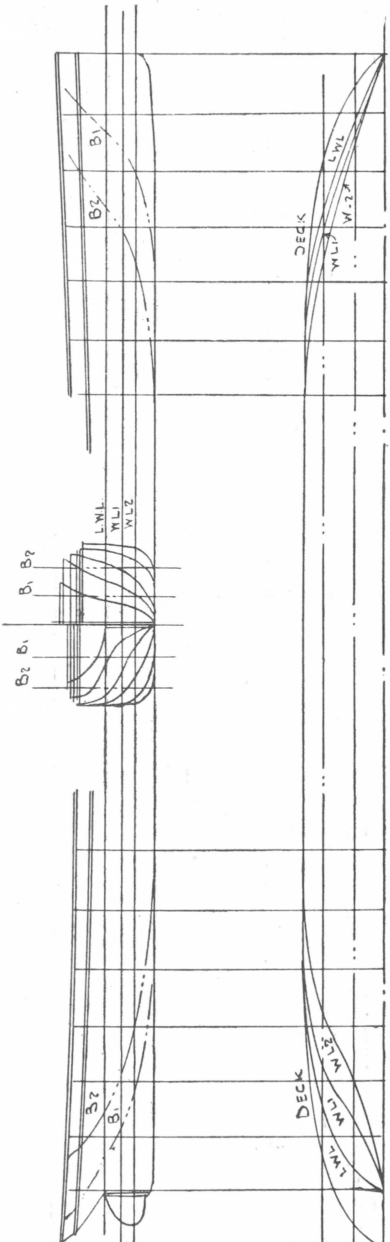


FIG. 103. SHEER DRAUGHT FERRY BOAT.

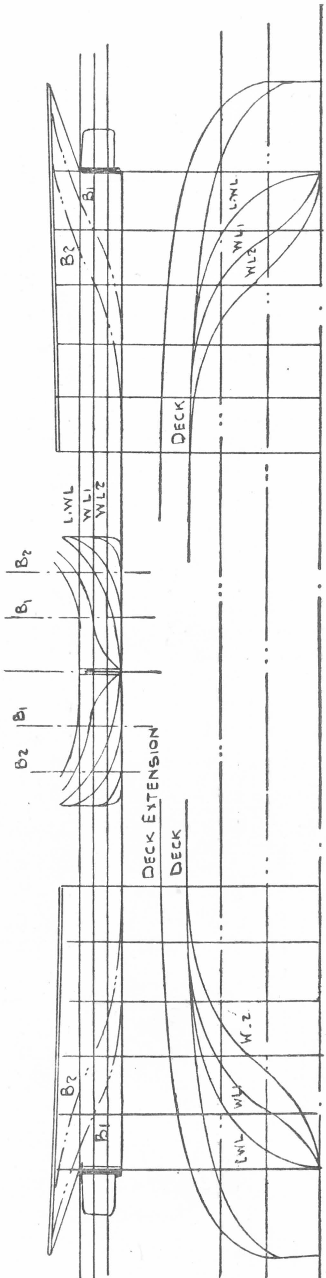


FIG. 104. SHEER DRAUGHT DOUBLE ENDED FERRY BOAT.

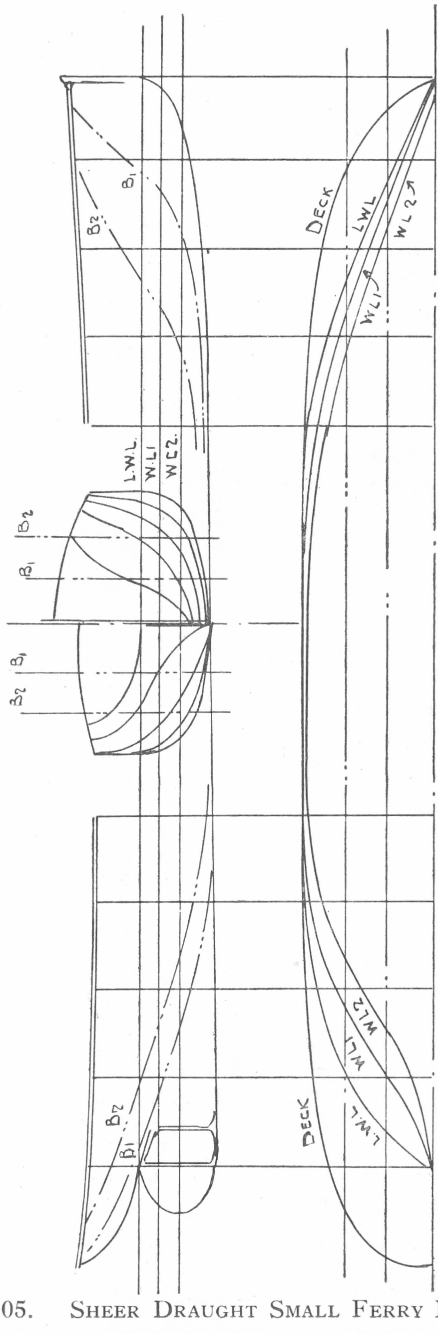


FIG 105. SHEER DRAUGHT SMALL FERRY BOAT.

about level with the wharf or jetty, but nevertheless they are extremely convenient in as far as loading and discharging are concerned.

Double ended ferry boats which have figured very largely in narrow waters where there is insufficient room to manœuvre, are generally of a pontoon shape in way of the parallel middle body and fined at each end below the water line; it is not uncommon to have transoms at each end, thus materially adding to the deck space.

Stability is an all-important consideration, and especially in the vessels of Types I. and II. Although it is undesirable to have a vessel too stiff, it is equally important that sufficient righting moment be provided so that the rolling is as easy as possible. Many American vessels have the sponsons, when wheels are fitted, extending from the stem to the stern, and this increases the deck area very considerably, but when it is borne in mind that the enormous moment given by such sponsons when accommodating some hundreds of passengers, would be sufficient to capsize the vessel at the least swell, the stabilising qualities must be assured. Again with larger ferry boats many deck saloons and other superstructures are usually fitted which tend to bring the centre of gravity of the vessel relatively high, thus care must be taken to ensure a sufficient metacentric height. With pontoon shaped craft this is more or less guaranteed, but if employed on cross channel work, the stiffness of the vessel would prove most uncomfortable in a sea way.

Fig. 102 gives the sheer draught of a large cross channel ferry boat, and while in the main not differing to a great extent from the passenger vessel, it will be noticed that the stern is suitably designed for the free "running-on" of rolling stock, etc. Fig. 103 shows the sheer draught of a vessel coming under Type II., and Fig. 104 gives a shallow draught vessel which would come under the same class. The latter is double ended, and it will be noticed that the deck is carried out to provide greater deck area. (See also Fig. 110). The last sheer draught, Fig. 105, is that of a small ferry boat which was recently built for South America. It will be noticed that her lines resemble, to a great extent, those of a large passenger launch, although the length-breadth ratio is somewhat greater than would be used for the launch.

Figs. 106 and 107 give the curves of weights, principal dimensions, etc., for the three types of ferry boats. These are for normal shaped vessels, although Fig. 107 gives the curves for the shallow draught boats up to and including 800 tons displacement. Of course full account must be taken of local conditions, with which the Designer should acquaint himself, since draught, breadth and freeboard may have to be modified to suit some special requirement.

A very typical type of vessel coming under Type I. is shown in the general arrangement (Fig. 108). This was built during the

late war for service in the Mediterranean Sea. Her principal dimensions are :—

Length, between perpendiculars ...	240′ 0″
Breadth, moulded	36′ 0″
Depth, moulded	15′ 0″
Draught, maximum, aft	10′ 6″

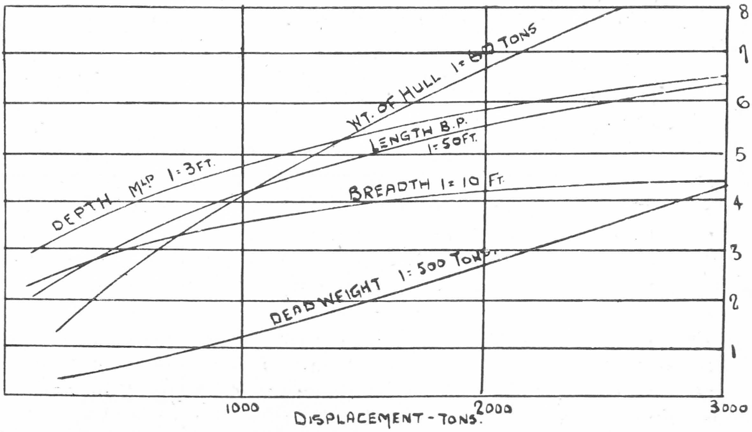


FIG. 106. CURVES OF DIMENSIONS, WEIGHTS, ETC., FERRY BOATS.

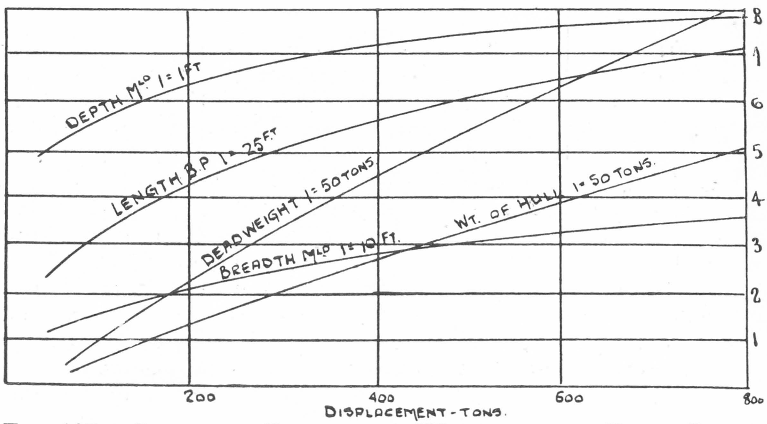


FIG. 107. CURVES OF DIMENSIONS, WEIGHTS, ETC., FERRY BOATS.

A single rail for a train is fitted to the main deck in the centre, and a space is allowed between the side houses for the train to be shunted on to the vessel. Only one carriage at a time can be shunted on, however, the short rail which runs across the vessel being continued to a turntable by which the carriages may be transferred to the longitudinal lines : although this method

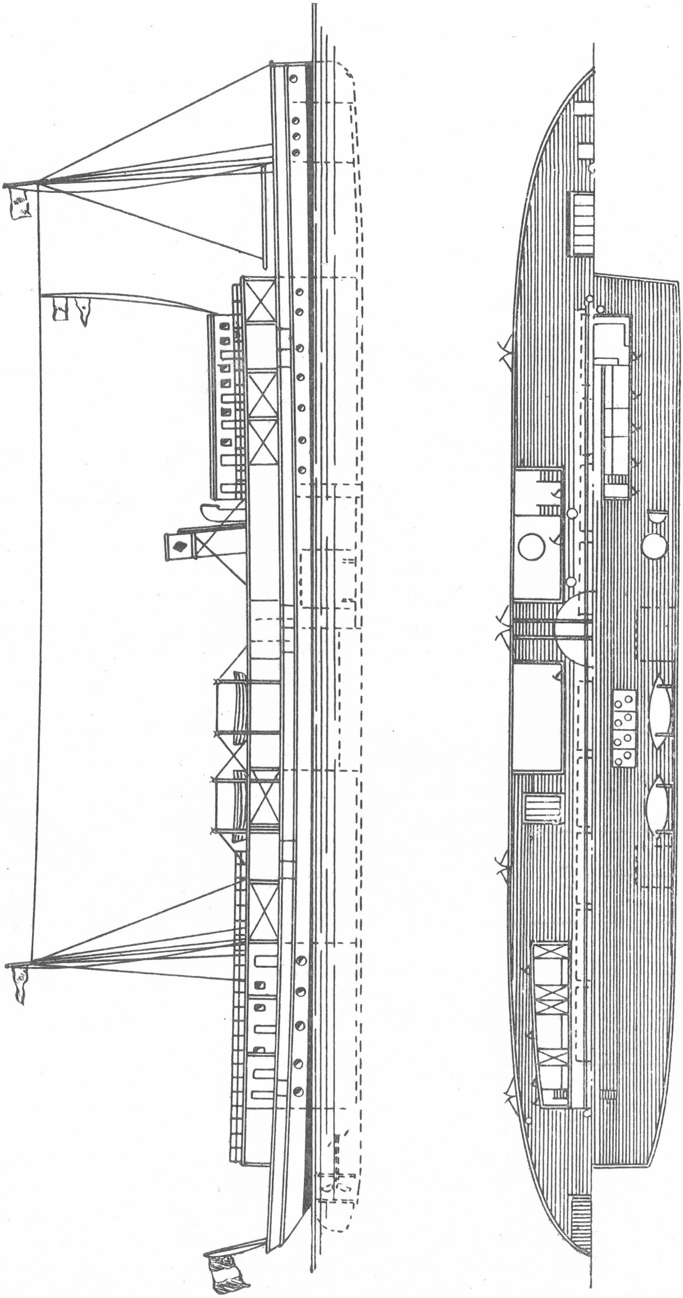


Fig. 108. General Arrangement Ferry Boat.

may take longer for the stowage of a complete train, it is nevertheless easier than running the train end-on since it saves any further movement of the vessel, when alongside. Two boilers are situated amidships, the funnels being arranged so that they clear the main deck space, and the space between the boilers is utilised as bunkers. The engine room is directly abaft the boiler rooms, and the twin sets are also arranged clear of the central track, on account of cleaning the engines, repairing etc., and also to allow for sufficient stiffening of the deck. The engines are of the triple expansion surface condensing type, developing a total of 900 I.H.P. The crew are accommodated well forward just abaft the fore peak, the lower part of which is fitted as a water ballast tank. The small hold, for mails, baggage, etc., is forward of the dining saloon, the deck space above being reserved for the accommodation of automobiles and waggons. The after end of the vessel is occupied by another small hold and the engineers' and Deck Officers' quarters. This is rather unusual, but it will be seen that all the space on the upper deck is reserved for passenger accommodation, state rooms, saloons and dining saloons being suitably arranged. The bridge and Captain's cabin stands at the forward end of the upper deck, leaving a good space for deck seating accommodation for passengers.

The next vessel, Fig. 109, shows the General Arrangement of a Great Lakes passenger ferry steamer. This vessel, it will be seen, is fitted with the side paddle wheels, but the sponsons, which are continuous all fore and aft, afford considerable protection to the wheels besides adding to the total deck area. As this type of vessel only runs on comparatively short trips, lasting about three hours, not many cabins are fitted. The crew and officers sleep at their homes ashore, and need only a mess room and saloon. All the remainder of the deck space is taken up by the seating accomodation. The upper and awning deck, lacking sufficient support, have diagonal tie-struts fitted, which prevent any tendency to racking in a side wind.

A double-ended ferry boat which was built for the River Parana is shown in Fig 110, and the principal dimensions of this vessel are :—

Length, between perpendiculars ...	140′ 0″
Breadth, moulded	52′ 0″
Depth, moulded	9′ 3″
Draught, maximum	5′ 0″

Two sets of compound surface condensing engines, each driving two screws, are fitted amidships abaft the boilers which, it will be noticed, are fitted as near the sides as practicable, so as to allow for the single train track which extends forward and aft along the main deck at the centre-line. Four first-class saloons, two at each end of the Engine and Boiler rooms, are fitted up with cushioned seats, etc., and the short forward and after decks can be used for the stowage of waggons and automobiles. Three cabins occupy the central portion of the upper deck, while at each

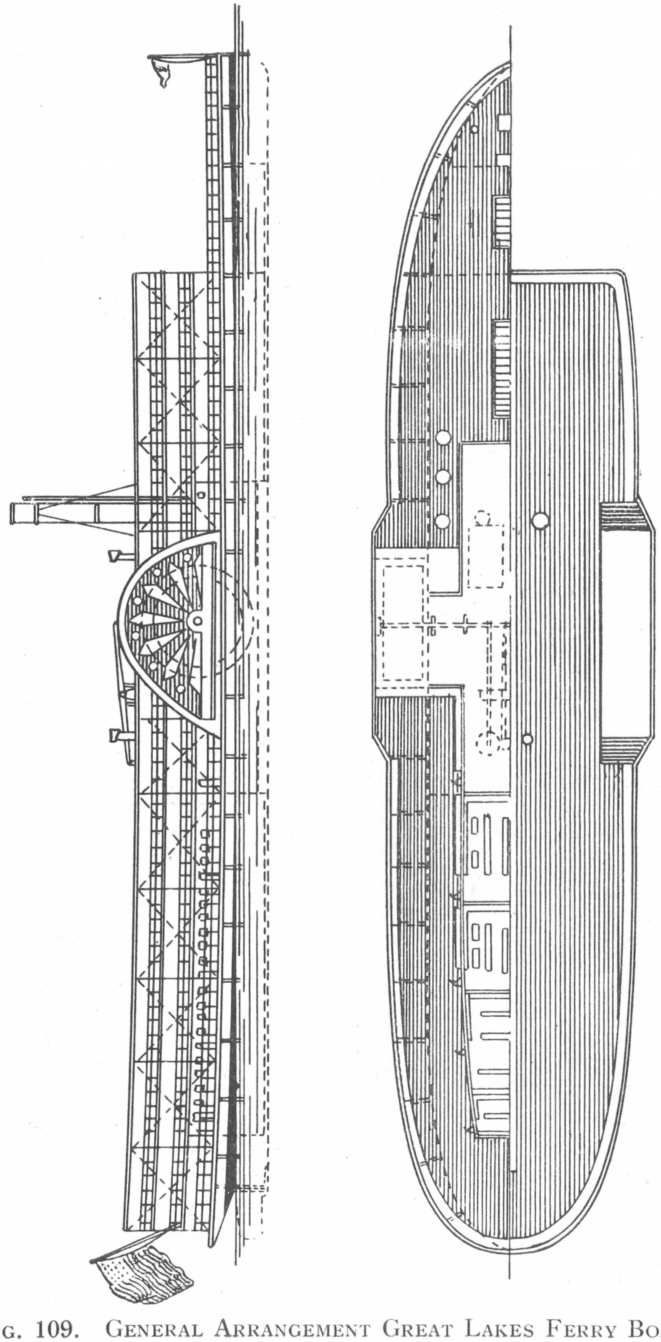


Fig. 109. General Arrangement Great Lakes Ferry Boat.

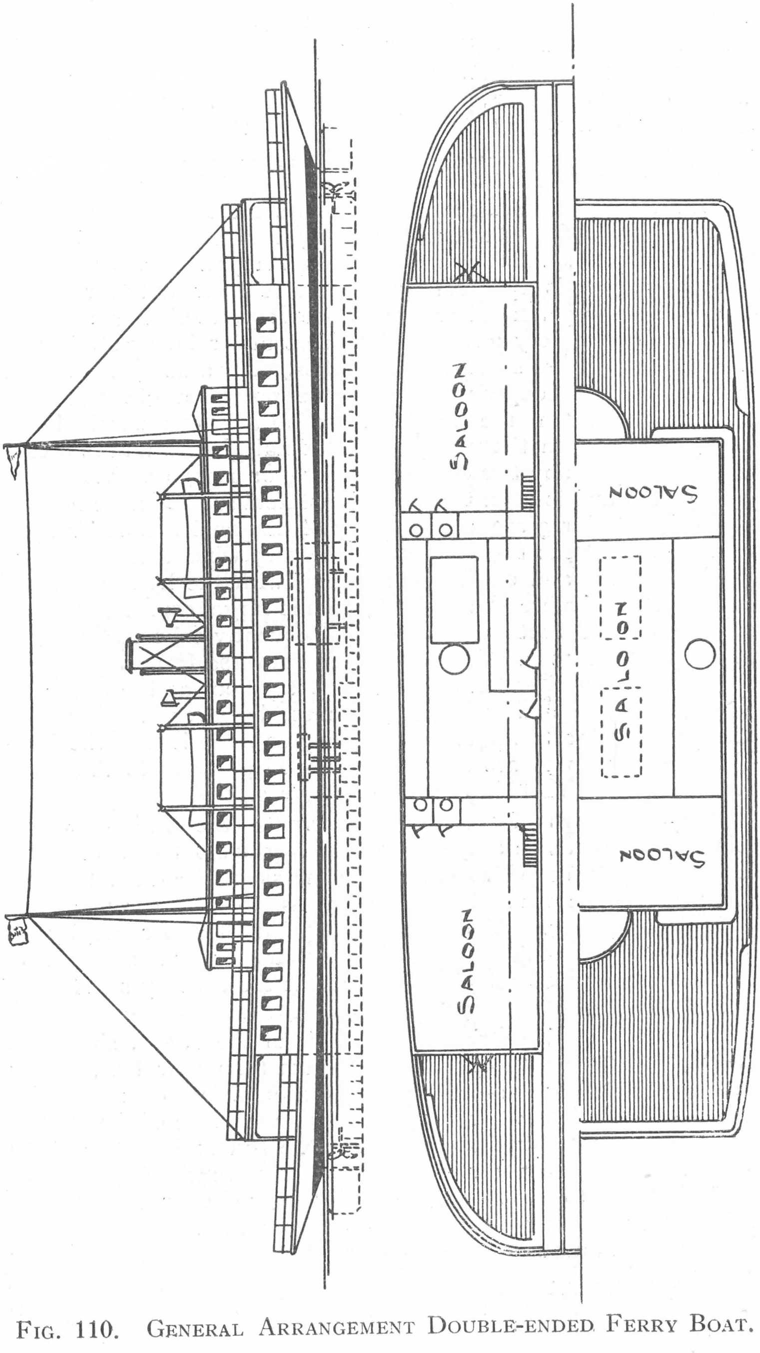


FIG. 110. GENERAL ARRANGEMENT DOUBLE-ENDED FERRY BOAT.

end of the deck house is fitted a semi-circular steering house. Four large skylights, fitted between the two funnels, provide light and air to the central cabin, which is bounded on the outside by the light shaft to the Engine and Boiler rooms. The remaining portion of the upper deck is fitted up with sparred seats, for the accommodation of passengers.

With the large sea-going ferry boats there are no abnormal requirements as far as structural strength is concerned, but with the small vessels which make often as many as ten or twelve trips per day, it is apparent that excessive wear and tear of the sides will be experienced unless sufficient protection is afforded by the fitting of very substantial fenders and rubbing strakes at such places that are most likely to suffer. Little difficulty will, in normal cases, be experienced with the provision of transverse strength, but when the length-depth ratio is excessively high, special stiffening in the way of longitudinal girders must be provided to prevent any tendency to hogging or sagging. When the depth of the hull is such that efficient stiffening cannot be accommodated, exterior girders in the way of diagonal ties and struts, etc., must be fitted; these are also necessary when there are more than two decks and efficient connection with the hull cannot be made. When the breadth of the bottom is large, especially should it be anticipated that the vessel will frequently take the ground, special precautions must be taken. The reverse frames are often doubled at every alternate floor, or at every floor as the case may warrant; the doubling reverse frames, however, usually only extend from bilge to bilge, and in many cases in lieu of the foregoing, deeper floors are fitted and flanged opposite to the usual reverse frame so that they form their own stiffening.

If the breadth of the bottom warrants the fitting of four keelsons, two each side of the centre line, then one of them, preferably the one furthest removed from the centre line, should have an intercostal keelson plate between the floors so as to afford support to the bottom plating. The continuity of the upper angles is important, and should be carried as far forward and aft as practicable, and well attached together at the ends by substantial plate brackets.

At least one side stringer, each side of the vessel, should be fitted unless the depth of the hull be less than four feet, and is usually of plain or bulb angle; it is preferable to fit in light, shallow draught boats two single angles on the face of the reverse frames, spaced equally distant between the underside of the beams and the tops of the floors, rather than fit one stringer of double angles, *i.e.*, back to back. By the former method their strength and stiffening is more evenly distributed over the area of the side framing, which needs special stiffening since the plating is usually comparatively thin.

Figs. 111, 112, 113 give the midship sections of the fore-

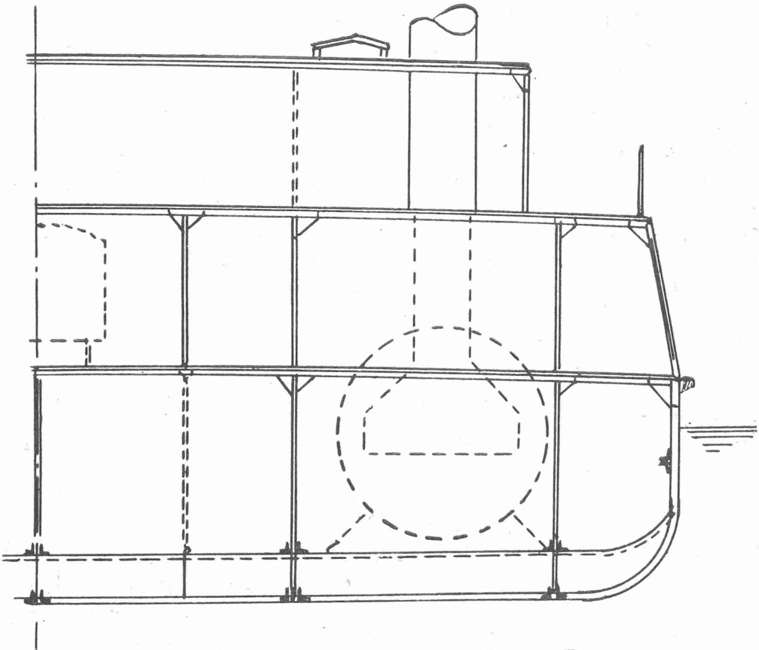


FIG. 111. MIDSHIP SECTION FERRY BOAT.

mentioned vessels, and particulars of their construction will be easily seen.

Many of the small ferry boats, which are often seen on small rivers, are built of wood, and in America where wood suitable for shipbuilding is very plentiful, many large boats are built of this material, and Fig. 114 shows the midship section of a ferry boat of the "double V" form. The keel, it will be noticed, is built on to the hogging piece, against which the garboard strake fays, the advantage of this method, which by the way is English—many Admiralty vessels being built in this fashion during the late war—is that in case of the keel being damaged or carried away, the planking is more or less untouched since it is fastened to the hogging piece, and refitting of the keel is a cheap and easy matter. The chine pieces, which are of oak, are continued as far forward and aft as possible, scarphs, with a double tongue being made at the butts. The main timbers are of sawn oak, in two pieces each side, joggled into the beam shelf, chine piece and centre keelson, and between every sawn timber American elm bent frames, three in number, are fitted, the necessary chocks and packing pieces being fitted to allow for the through fastening of the stringers, etc.

The deck arrangements vary considerably according to the service to which it is intended to put the vessel; sea-going craft

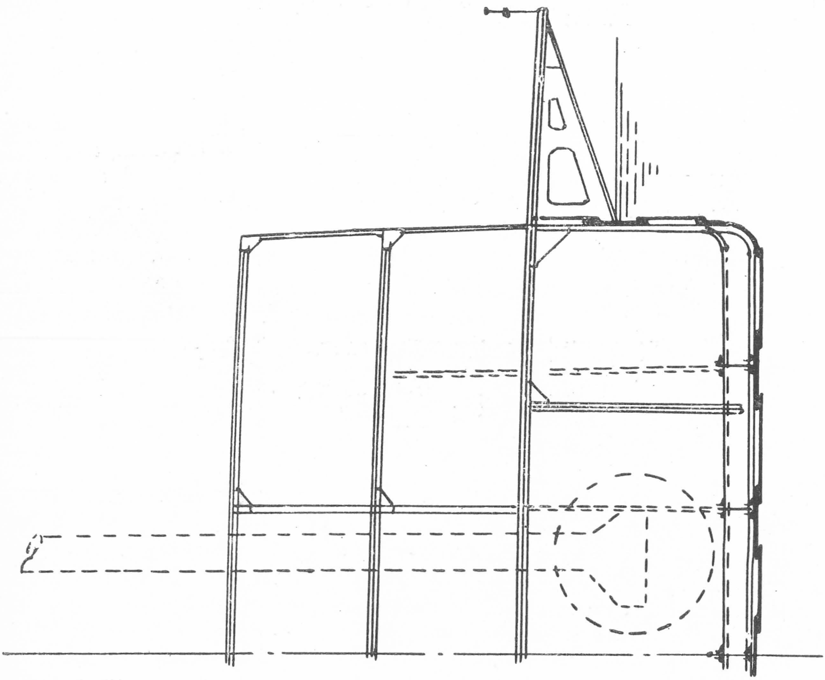


Fig. 112. Midship Section Great Lakes Ferry Boat.

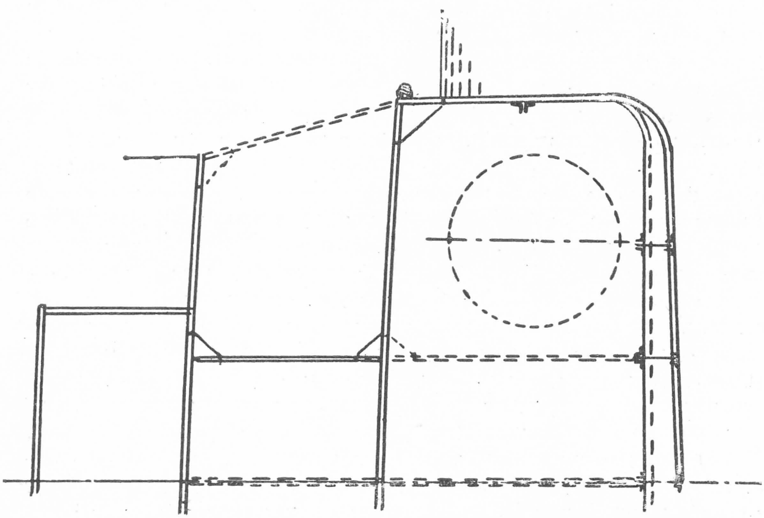


Fig. 113. Midship Section Double-ended Ferry Boat.

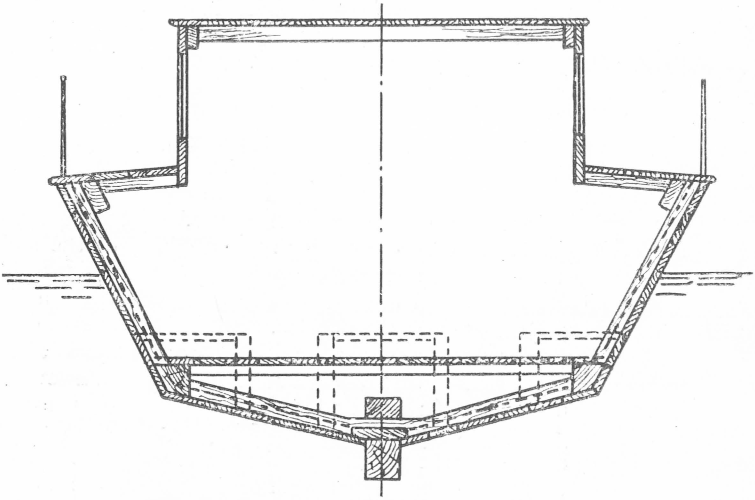


FIG. 114. MIDSHIP SECTION WOOD FERRY BOAT.

usually have a steam windlass forward, although when trains are carried it cannot be accommodated in the centre line of the vessel, in which case two windlasses, either steam or hand, according to the size of the anchors, are placed on each bow. If derricks are used for working the cargo, when such is carried, steam winches are almost invariably fitted for speedy discharge; the hold is usually forward, and it is often possible to lead a messenger chain forward to the windlass. A mast or pole is always fitted for carrying the lamps, etc., and in a large vessel two masts are fitted for the sake of appearance.

A steam steering engine is necessary with large craft, and these should be of the "all-round" type, and fitted generally below the bridge or well aft. Hydraulic gear of the Heleshaw type has been supplied to many large vessels with considerable success, but this gear is really too large and cumbersome for vessels under 900 tons displacement, and even for larger vessels a steam set has many advantages. With river craft of small dimensions the usual bridge double reduction gear is adopted, and with the very small boats a simple tiller is the best. With double ended vessels two steering gears must of course be used, although in some cases the one gear has been specially made to take the leads from the forward and after rudders. By a gearing arrangement both rudders have been allowed to turn, of course, in the same direction, but it is doubtful whether the increased efficiency—if any—warrants the increase of cost that this method involves.

It is most important that the rudder shall be well protected under the counter of vessels of this type, since it may suffer damage when turning away from the wharf, and it is often a difficult

proposition to fit a sufficiently large rudder in proportion to the immersed lateral plane. It is therefore necessary to fit two or more rudders to allow efficient manœuvring capabilities. The spacing of the rudders across the vessels is in this case about the overall length of the rudder, and instead of the usual arc quadrant, built up of plates and angles, the rudder heads are keyed on to iron or steel bars, rectangular in section, and which have their ends flattened out and punched for taking the connecting pieces. The connecting pieces may be of chain shackled on to the arms, although in many cases the connecting rod is a bar, of the same section as the arm, and welded to fork shape at the ends so that one piece of metal fits above and one below the arm, and allow a bolt to pass through the three thicknesses. The leads from the steering engine or gear are then shackled on to the arms of the two outer quadrants. The ratio of the rudder area to the immersed lateral plane varies between 1/8 and 1/20, according to the ratio of length, draught, and fullness of hull. The greater the draught and the fuller the vessel, the greater will be the area of the rudder. When the lines of the hull and the length-draught ratio are normal, and more than one rudder is fitted, the total areas of the rudders should be in the following proportion :—

2 rudders, $A = a + 1/3a$.
3 rudders, $A = a + 1/2a$.
4 rudders, $A = a + 2/3a$.

where A = the total area of the rudders,
and a = the area of a single rudder, as given by the ratio with the immersed lateral plane.

Reference has been already made of the Kitchen reversible rudder under lighters and barges, but further note must be made here. The fine adjustment, both as regards steering and speed, that can be made with this rudder, makes it of particular value with small ferry boats. The direct control from the bridge gives the Captain full control over the vessel, and the easiness of reversing, and the capability of being able to turn in the length of the vessel, allows the vessel to come alongside with comparative ease. See page 105.

The usual deck fittings, such as bollards, fairleads, etc., should be carefully arranged to facilitate the mooring of the vessel, and in small vessels, in addition to the two bollards on the bows and quarter, two more bollords are fitted on each side at suitable distances apart, amidships, for allowing cross ropes to be run ashore. Rails or bulwarks must be fitted at the sides of the vessel all fore and aft, if passengers are carried, these must not be less than 2ft. 6ins. in height, and in large vessels the height of the rails is usually between 3ft. and 3ft. 6ins. Portable rails are adopted in way of accommodation ladders or gangways.

The deck seating accommodation is generally determined by allowing 1.5 ft. of seat per person, or by dividing the clear deck space by 6. A suitable number of buoyancy seats must be provided,

these of course counting as seating accommodation. Suitable lifebuoys, and other life-saving appliances must be supplied in accordance with the Board of Trade's requirements, and according to the service, for which the vessel is intended.

Small ferry boats working on very narrow rivers are not always supplied with anchors, but in large craft these of course become necessary. They are not, however, of excessive weight, a vessel engaged on cross channel service having two bower anchors of 5 cwts., and a third anchor of $2\frac{1}{2}$ cwts., all excluding the stock, a suitable length of cable, about two lengths of sixty fathoms each, of 1 1/16 ins. short link chain, being supplied. Vessels working under Type II., and of about 80 to 120 tons, registered, under deck, would have about 60 fathoms of 13/16 short or stud link cable, and three anchors of 3, 3, and $1\frac{1}{2}$ cwt. each, respectively, ex stock.

The propelling machinery of ferry boats is, in the case of the large vessels, of the triple expansion type of steam engine. Turbines and electric motors have been experimented with but have been found to be very unsuitable for vessels of this class. Marine oil engines have been installed on several recent craft, but great care must be taken in the selection of the type of motor.

When it is remembered that ferry boats have to do greater manœuvring than any other class of boat, an engine which depends entirely upon compressed air for starting and reversing is really unsuitable, since if considerable reversing happens to be needed on any one occasion and the supply of compressed air becomes exhausted, the engines, until the supply has been replenished, are rendered *hors de combat.*

Sometimes a separate compressing pump and motor are utilised to overcome this difficulty, but even then if the supply is exhausted, the air supplied by the pump is only capable of turning the engine at very low revolutions per minute. There are several direct reversing engines on the market. The Bolinder engine, for instance, has an auxiliary reversing pump on the main fuel pump rocking arm, which when the speed of the engine is sufficiently low explodes a charge, as the piston is nearing the completion of the up stroke, and causes a "back-fire," which makes the engine reverse, and then the main pumps come into play again. Reversing gears are sometimes fitted, but unless of a good, reliable make, they are a great source of trouble. The "brake" type of reversing gear should not be used since with considerable reversing the gear becomes overheated, and may seize. Another point, many of the reversing gears at present on the market are geared down for the reverse movement, and the speed astern is often less than one quarter of the ahead speed, a fact which has a great disadvantage with this class of vessel.

With double ended craft the propeller shafts are sometimes continuous from propeller to propeller, the engines being connected

to them by gears or chains. The propellers must be oppositely made, *i.e.*, one must be right handed and the other left, since both propellers will be turning at the same time. The advisability of this plan is still open to much controversy, but in the case of twin screw boats there is a great advantage in fitting the engines well against the side of the vessel, thus leaving the centre of the deck clear for the fitting of railway lines, etc. When the engines are interposed between the tail shafts, some suitable clutch or engagement gear must be fitted, and it is advisable, as a precaution against mistakes by the Engineer, to fit right and left handed propellers at each end, thus whichever way the vessel be going, the engines will be ahead, and at the order astern the reversal of the engines will be the same whichever propeller is engaged. In the foregoing, ahead and astern is spoken relatively to the main direction of the vessel.

Side paddle wheels are undoubtedly the best means of propelling this type of vessel, since far greater power in manœuvring and greater facility in coming alongside are gained by this mode of propulsion; on the other hand, however, the paddle boxes are open to great damage, are cumbersome, and render the embarkation of trains, difficult. In America many paddle wheels are built, owing to the fact that wood is plentiful, and the wheels made from this material are easily repaired in the case of damage, whereas a screw if damaged or broken may delay the vessel several weeks should it be working at a considerable distance from any repairing works or foundries.

Engines for paddle wheels, owing to their small revolutions per minute, are of greater weight and occupy more space than the compound or triple expansion engines, which have decided disadvantages in light draught craft, and if a stern wheel is fitted, the great distance between the engines and boilers, each being fitted at the ends of the vessel, in order to keep it on an even keel, carries with it many disadvantages. In Walter Pollock's book, "'Hot Bulb Engines and Suitable Vessels," an arrangement is given whereby a semi-diesel engine can be suitably geared down to drive paddle wheels. The gearing, however, is excessive, the revs. of the engine being anything between 300 and 400, and the revs. of the wheel being at the most 20, and the further necessity of bevel gearing, for the motor must be fitted longitudinally, causes considerable loss of power.

The usual Scotch type of marine boiler is installed in ferry boats, except in the light draught vessels, as used on American and Tropical rivers, when the loco type of boiler is fitted. The bunkers are usually arranged longitudinally along the boiler room. When it is desirable to keep the centre part of the deck clear, long boilers, sometimes double ended, are fitted as close to the side of the vessel as possible (usually about two feet from the face of the reverse frames), in which case the bunkers are arranged athwart-

ships at the forward end of the boiler room, or between the boilers, with suitable openings to each stoke hold.

The fuel tanks, when oil engines are installed, are often strapped to the frames in the engine room, or against the forward engine room bulkhead, a small daily service tank being fitted on a bracket shelf at a suitable distance above the engines to provide a sufficient head or pressure to the fuel pumps. The Board of Trade, however, require the fuel tanks in passenger vessels to be enclosed within a separate compartment, bulkheaded off by transverse, or if needed, longitudinal oil-tight bulkheads.

Side paddle wheels are treated in Chapter 9, which deals with passenger vessels, and Fig. 115 gives the speed and power curves for ferry boats. These are based upon the Admiralty coefficient formula, and treat vessels of similar form. Some allowance must be made, therefore, for vessels with high length-depth ratios and large length-breadth ratios, which will require greater power than given; the power required for vessels of extreme proportions often exceeds 10 per cent., but generally, unless the after lines be very full, an increase of 5 to 7 per cent. should be sufficient. The curves give the I.H.P., but if the B.H.P. is required, the reader may refer to the chapters dealing with launches and small passenger vessels, or by making an allowance on the curves of between 10 and 15 per cent. according to the speed of the engines, the greater the speed, of course, the greater the allowance which must be made.

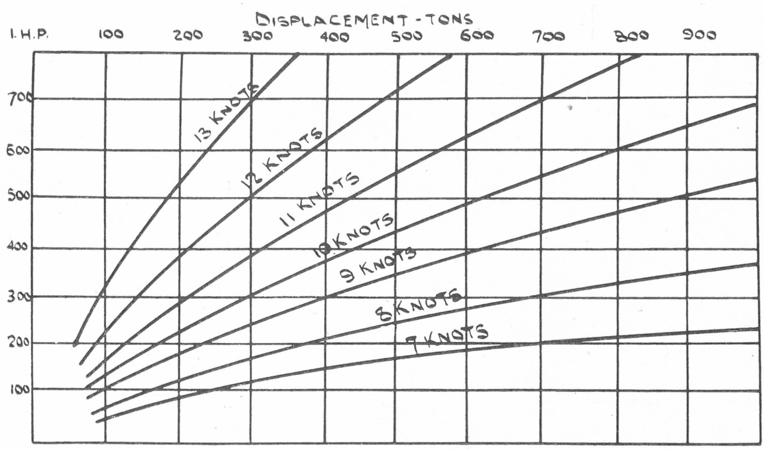


FIG. 115. SPEED, POWER, CURVES FERRY BOATS.

Fig. 116 gives the diameters, pitches and areas of developed surface of propellers suitable for this class of vessel, and those driven by steam sets. The developed area given is the total, and

is based upon three-bladed propellers which have been fitted to some recent vessels, and for four-bladed propellers the necessary alteration must be made.

The following edge, as well as the leading edge of the propeller, should be as fine as possible, and the fact that a fair speed astern

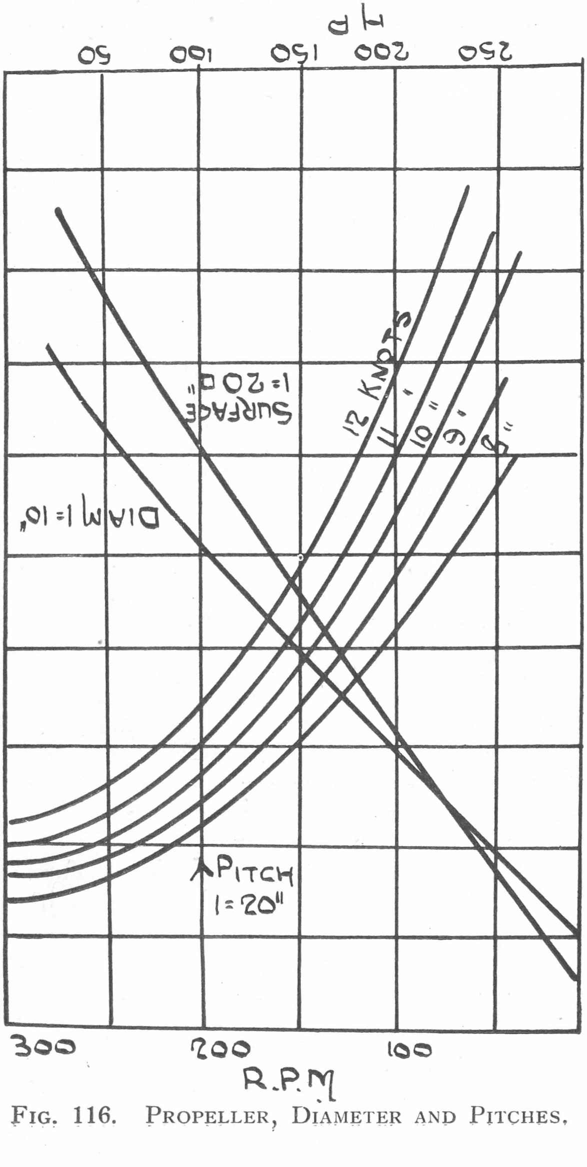


FIG. 116. PROPELLER, DIAMETER AND PITCHES.

is important, makes it necessary to suitably design the propeller. The greatest width of the developed blade is usually at somewhat less than two-thirds the diameter, and a little set back is usually given to the blade. The contour of the developed blade should show a swell on the leading and following edges, and a greater area than usual should be given near the tip, making the latter comparatively broad. The pitch diameter ratios between 0.8 and 1.25 are normal, although in the case of the propeller driven by oil engines the ratio is considerably less.

The reversing propeller, which came on the market a few years ago, is very unsuitable for ferry boats. It may give good results under normal conditions, but when constantly being reversed, the wear and tear is very considerable, and frequent repairs and renewals make the otherwise efficient contrivance somewhat costly.

CHAPTER 11.

COASTING VESSELS.

At the Engineering Conference, held at the Institution of Civil Engineers, in 1921, Mr. W. L. Roxburgh, speaking to the Shipbuilding Section, dealt with the necessity for developing our coasting trade, and pointed out some of the methods whereby this could be accomplished. There are, he said, about seventy smaller ports situated all round the coast which could be developed into most valuable agencies for handling goods which are now transported by rail. Some of these would require to be improved and equipped with modern appliances, but such expenditure would be wisely undertaken in view of the beneficial effects upon the cost of industry. The existence of a highly developed coastal shipping trade would lead to a general cheapening of goods. Particulars of coastal tonnage are also given in the above mentioned paper.

The design of coasting vessels presents problems of its own, one of the most important being to obtain a favourable deadweight displacement ratio in spite of the handicap of disproportionate machinery installations. Questions of speed and minimum draught of water, crew accommodation—which, unfortunately, cannot be generous in such confines—and in many instances, a limiting length or breadth have all combined to bring about certain types, at least in the smaller classes, peculiar to the areas within which the vessels trade.

In Fig. 117 curves are given for the determination of the approximate dimensions, etc., of raised quarter-deck coasting vessels.

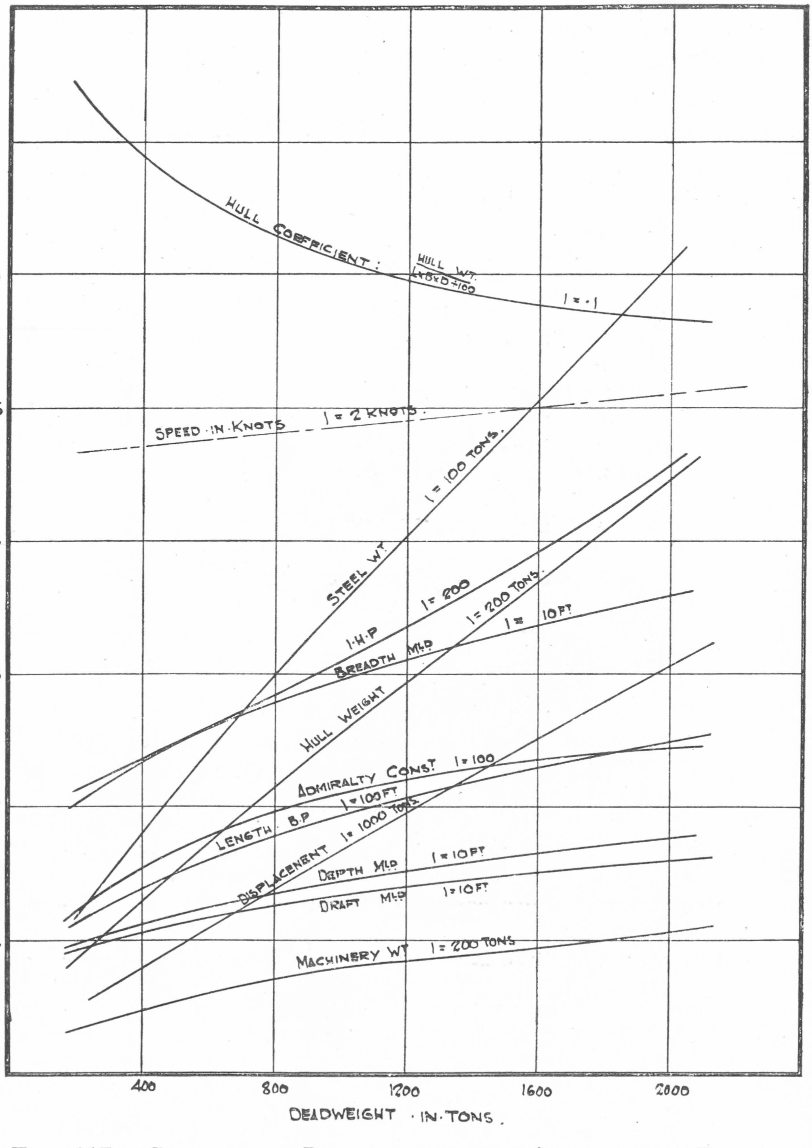


FIG. 117. CURVES FOR DETERMINATION OF APPROXIMATE DIMENSIONS OF RAISED QUARTER-DECK COASTING VESSELS.

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For a vessel of 800 tons deadweight, the following particulars are taken from the curves in Fig. 117 :—

Length B.P. ...	180.0 ft.	Hull Weight ...	430 tons.
Breadth mld. ...	27.75 ft.	Machinery Wgt.	140 ,,
Depth mld. ...	13.70 ft.	Steel Weight ...	300 ,,
Draught mld. ...	12.75 ft.	Displacement ...	1,370 ,,
Hull Coefficient ...	0.629	Admiralty Constant,	195 ,,

I.H.P ... 570.

The weight of hull is made up as follows :—

Item.	Tons.
Steel and Rivets	300
Forgings and Castings	17
Anchors, Cables, Hawsers	12
Cement, Paint, etc.	46
Carpenter work	25
Joiner work	9
Plumber work	8
Deck and Aux. Machinery	4
Stores, Outfit and Sundries	9
Hull weight ex. Machinery	430

Cube Number (L × B × D ÷ 100) = 684

$$\text{Ratio } \frac{\text{Hull}}{\text{Cube}} = 0.629$$

$$\text{Displacement} = \begin{cases} \text{Hull} = 430 \\ \text{Machy.} = 140 \\ \text{Dwt.} = 800 \end{cases}$$

1,370 tons.

With an Admiralty constant of 195 the speed corresponding is 9.6 knots.

In Fig. 118 a curve is given for the average Block Coefficient of coasters on a base of :— $\dfrac{V}{\sqrt{L}}$

In raised quarter-deck coasting vessels the propelling machinery is generally situated aft, for if placed amidships, giving one hold forward and one aft, the holds would be too small to be of any value, particularly in small vessels. The presence of the shaft tunnel in the after hold would still further reduce the capacity

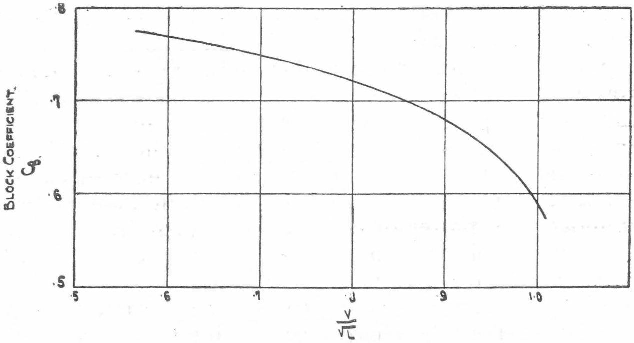

FIG. 118. CURVE OF AVERAGE BLOCK CO-EFFICIENT OF COASTERS.

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for cargo. The arrangement of machinery aft not only gives a long clear hold, but reduces the initial cost, due to the saving in the cost of steel work involved in the shaft tunnel and additional necessary bulkheads, as compared with an arrangement where the machinery is placed amidships. A reduction in shafting is also obtained.

As some coasting vessels load in tidal harbours in which the ground may be neither smooth nor level, and as the tide may leave the vessel high and dry, perhaps when loaded, the strength of the bottom should be increased beyond what is otherwise necessary. It is not uncommon in vessels trading as above to find the shell plating set up between the frames.

The coasting vessel is one which as far as results from experimental tanks are concerned has been sadly neglected.

Rear-Admiral D. W. Taylor in his book "The Speed and Power of Ships," gives curves from which it is possible to determine the effective horse-power of almost any ship, provided the same form as he gives is used. The limits of his curves make provision, however, for a displacement of only 1,700 tons on a length of 220 feet. To suit the above class a displacement of 2,300 tons would be required on such a length. Mr. Baker, of the National Tank, has a great record of experimental work to his credit, but he has not given anything to suit the coasting type of vessel. The experiments of Professor Sadler have not been on a low enough length and breadth proportion.

The designers and builders of coasters are still waiting for such information as only model experiments can give, and the experimenter who undertakes this work will undoubtedly earn the gratitude of a large body of shipbuilders and engineers.

What is desired is to know what probable modifications in resistance would arise from alteration in length with given beam

and draught, or with a given length what increase in resistance would result in an increase in beam. Would it be more economical to make a vessel broad and relatively fine for a given displacement or narrower and fuller? What increase in power would follow from making a ship shallow and full rather than deep and fine? What increase in power would be required for increase in speed? At present, unless the builder has had many years of experience and an abundance of data, the effect of such modifications as outlined above is a matter of conjecture. Furthermore, problems are constantly cropping up to which the records of even the most experienced offer no solution.

With the coasting type of vessel it is unusual to run progressive trials, generally through lack of interest in the performance at all speeds, sometimes through pressure of time, and occasionally because of the cost involved. Even where the results of such trials are available, they are often useless in giving information in the direction required.

Model experiments on other classes of vessels have brought about economy in power and cost, and it is unlikely that the coaster would be out with the possibility of improvement. Generally speaking, the best form and proportions for these over-driven ships may have been adopted, but were a systematic series of experiments carried out with models of the type, all doubt on the matter would cease to exist.

The extraordinary conditions under which these vessels run involve an expenditure of power in relation to their size, which would be considered most uneconomical in larger ships. Take, for example, a coaster of 140 ft. in length, a beam of 24 ft., and a draught of 10 ft. 6 ins., displacing 750 tons. Increased up to 400 ft. length—the basic conditions of Baker and Kent's mercantile series—the dimensions would be 400 ft. by 68.5 ft. by 30 ft., the displacement becoming 17,650 tons. The speed of the actual ship is 9 knots, the proportional speed of the 400 ft. ship is over 15 knots. If Kent's 1919 paper be referred to, it will be found that some extraordinary proportions of ships are there included and experimental results given. Even Kent's work, however, leaves this case untouched, for although the displacement has been equalled in certain models of extreme width, the draught has not been in harmony with coaster practice, nor has the speed been as great as that actually obtained by these vessels.

The P value of the above case is about .63, which falls outside the range of Kent's result at its appropriate displacement. It has, however, been reported that steps are being taken in a neighbouring northern country, which owns a large number of vessels of the smaller type, to instal an experimental tank for the elucidation of the particular problems associated with this class of vessel.

The general arrangement of a typical raised quarter-deck coasting vessel of 800 tons deadweight is given in Fig. 119.

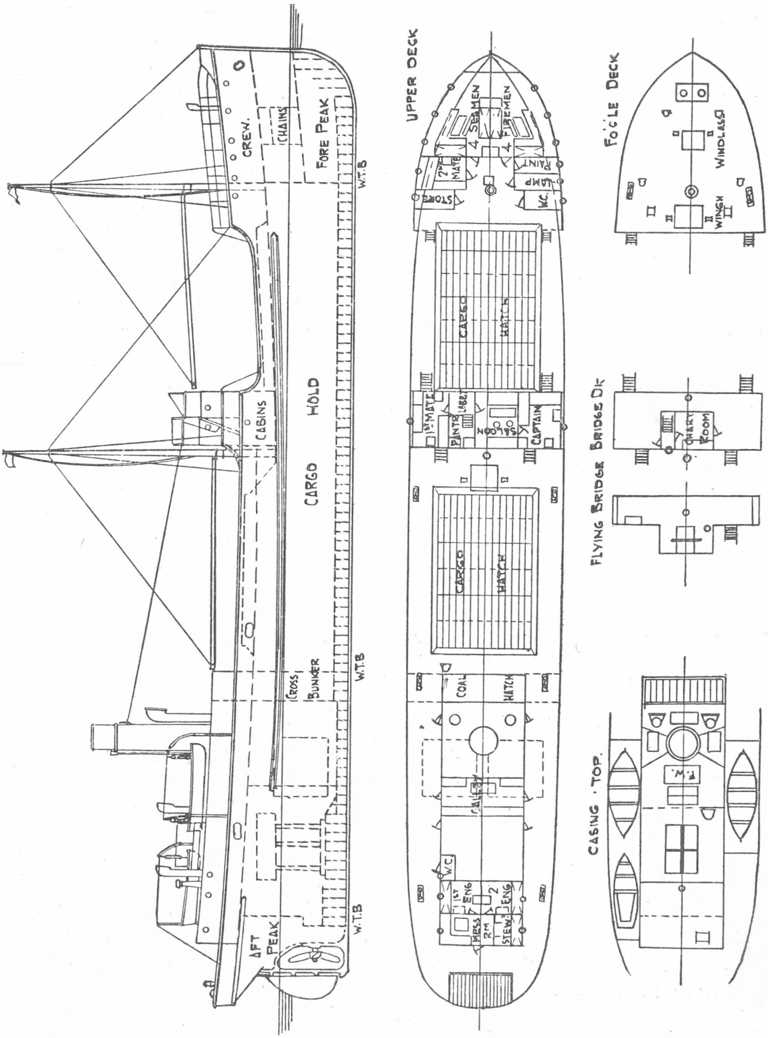

Fig. 119. Typical General Arrangement of a Raised Quarter-deck Coasting Vessel.

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From the figure it will be seen that the raised quarter-deck extends from right aft to well forward of amidships. Forward above the main deck is the forecastle, while on the forward end of the raised quarter-deck is the bridge. The propelling machinery is placed aft, with a short cross bunker directly in front of the

boilers and in the same watertight compartment as the machinery. Forward of this is a single cargo hold, extending from the cross bunker to the fore peak bulkhead. There are in all three transverse watertight bulkheads, viz., the fore and aft peak bulkheads and the bulkhead dividing the cross bunker from the cargo hold.

Provision is made for water ballast in a cellular double bottom extending the full length of the cargo hold and cross bunker, and in both the forward and after peaks.

The mess-room and accommodation for the captain and mate is amidships under the bridge, and the engineers' and steward's accommodation is arranged in a steel house on the raised quarter-deck at the after end of the engine casing. The galley is situated between the engine and boiler casing at the quarter-deck level. The crew are berthed in the forecastle, and on the aft side of the forecastle bulkhead is fitted the second mate's cabin, paint room, lamp room, store and w.c. The officers and crew number in all 14.

Two wood masts are fitted, each of which carries a 3-ton wood derrick for loading and discharging cargo. Two steam winches 6″ by 10″, one placed adjoining each mast, are provided for working the cargo. The cargo hold is served by two self-trimming hatchways of large size. The capacity of the coal bunker is 65 tons.

A steam windlass with quick warping ends is provided on the forecastle deck and a steam double-barrel capstan for warping purposes is arranged right aft at the level of the bulwark top. The steering gear is of the combined steam and hand type, 6″ by 6″, and is situated on the flying bridge.

Two lifeboats, each 17 ft. long, are placed one on each side of the ship at the sides of the boiler casing. There is also a 15 ft. dinghy on the port side abreast the engine casing.

A fresh water tank of 800 gallons capacity is placed on top of the boiler casing.

A complete installation of electric light is now generally fitted on coasters, a 3.3 K.W. generating set being usual.

The propelling machinery consists of a set of triple expansion engines, having cylinders 14, 23, and 39 ins. in diameter by 27″ stroke. Steam is supplied by two single-end cylindrical boilers, each 10′ 9″ in diameter by 10′ 9″ long, working at 180 lbs. per sq. inch and natural draught. The machinery is capable of developing 570 I.H.P.

The auxiliary machinery comprises one centrifugal type circulating pump, one auxiliary feed pump, one ballast pump, one general service pump and one feed filter. An ash ejector is commonly fitted.

The midship section of the vessel is given in Fig. 120 and the equipment of anchors, cables and hawsers is as follows :—

3 Bower Anchors (stockless), 48 cwt. collective weight.
1 Stream Anchor, $4\frac{3}{4}$ cwt. ex. stock.
1 Kedge Anchor, $2\frac{1}{4}$ cwt. ex. stock.

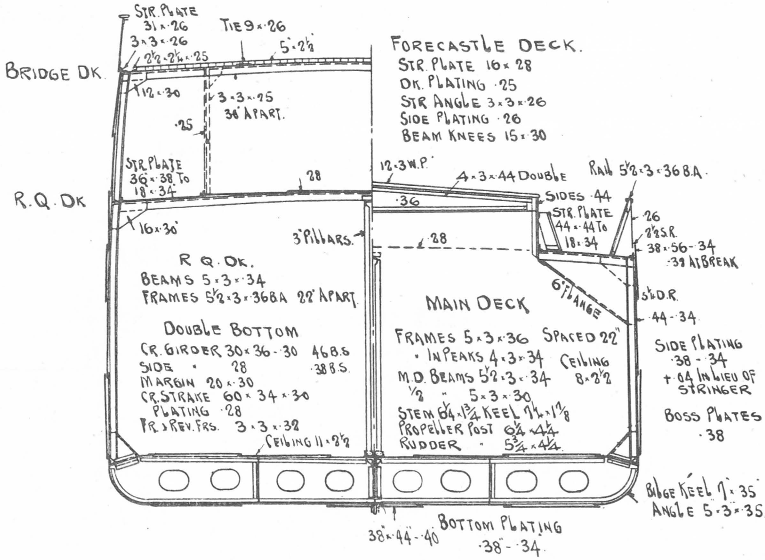

Fig. 120. Midship Section of a Coasting Vessel.

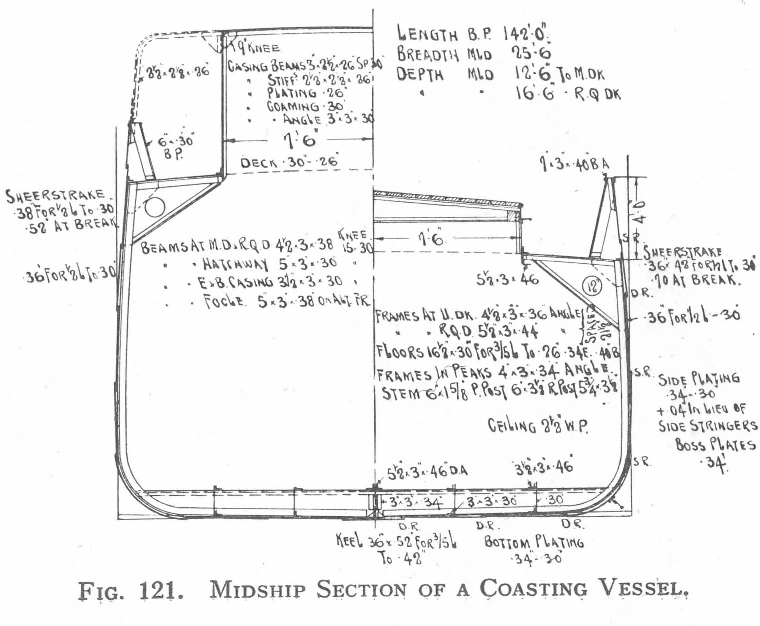

Fig. 121. Midship Section of a Coasting Vessel.

210 Fathoms of $1\frac{1}{4}''$ stud link chain cable.
75 ,, $2\frac{3}{4}''$ steel wire towline.
90 ,, $2\frac{1}{4}''$,, ,, hawser.
60 ,, $3''$,, ,, stream line.
90 ,, $1\frac{1}{2}''$,, ,, warp.

The Midship Section of a single bottom coaster 142′ in length is given in Fig. 121.

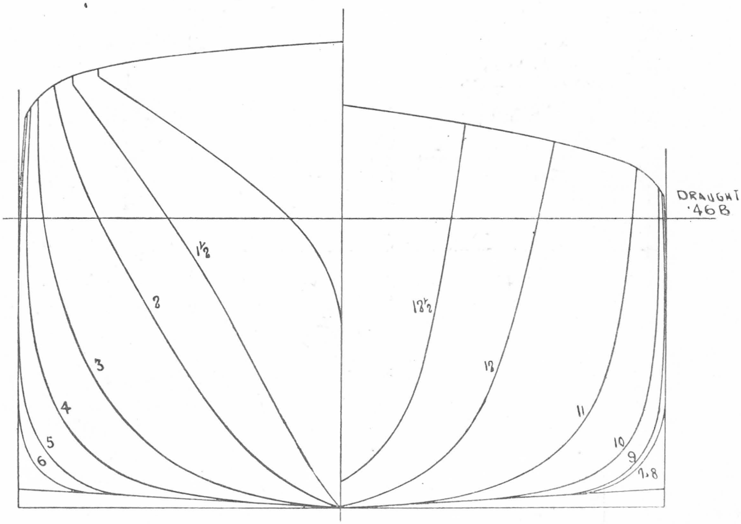

FIG. 122. BODY PLAN OF A COASTING VESSEL.

The Body Plan of the 800 ton dwt. vessel is shown in Fig. 122. The sheer forward is 4′ 6″ and aft 2′ 9″. No. 1 section is at aft side of rudder post.

The C.G. in light condition (hull and machinery) above base of coasters with long raised quarter-deck, bridge, forecastle and double bottom is about .72 mean depth between main and raised quarter-deck.

In Table A particulars are given of cast-iron propellers for coasters.

TABLE A.

No.	Speed in Knots.	I.H.P.	R.P.M.	Blade Area, sq. ft.	No. of Blades.	Pitch, Feet.	Diameter Feet.
1	10.9	550	102	33	4	12.5	9.5
2	10.3	630	108	30	4	12.0	9.3
3	10.9	700	101	35	4	13.25	10.0
4	10.7	730	90	38	4	13.5	10.5
5	11.4	760	103	35	4	—	10.0

The ratio of net tonnage to gross tonnage in coasters may be illustrated from the following list of vessels of the type. The particulars have been extracted from Lloyd's Register.

No.	Name of Vessel.		Gross Tonnage.	Net Tonnage.	Net Gross.
1	Ardbarten	...	1,350	800	.592
2	Achroite	...	1,196	710	.593
3	Agate ...	...	824	397	.482
4	Tenet ...	...	606	233	.385
5	Gowerian	...	449	186	.414

From the above list it may be stated roughly that the proportion of net tonnage to gross tonnage is for coasting vessels.

$$\text{Net} = \tfrac{1}{2}\ \text{Gross.}$$

MOTOR COASTERS.

In no branch of naval architecture are the various essentials more irreconcilable than in the coasting trade, and until the advent of the semi-Diesel engine the desideratum of the owner for deadweight carrying capacity was largely counteracted by the size and weight of machinery.

In the design of motor vessels there are a number of new factors to be taken into account, as follows :—

(1) Oil engines weigh very much less per horse power than the usual form of steam machinery, and thus less displacement is required.

(2) The revolutions of the engine are higher than those of steam machinery of the same power, which alters the design of the propeller and the lines aft, if the best results are to be obtained.

(3) The engine room should be of different design, and it is desirable to have a light and well ventilated machinery space.

(4) Due to the lighter machinery, the shaft line must be kept low so as to obtain the proper immersion of the propeller in light condition.

One of the great advantages of the marine oil engine, for small vessels, is the saving in space occupied by the oil engines compared with the corresponding space required for modern steam machinery of the same horse power.

In a coaster of 250 tons deadweight a saving of 9′ 9″ in the length of the machinery space is made and 1,500 cubic feet in capacity. The cubic capacity of the hold is increased by about 15% without increasing cost. Alternatively, the same cubic capacity as that of a steam ship could be obtained in the oil engined vessel with a hull about 12% smaller.

The first full powered oil-motor coasting cargo vessel was built at Ardrossan. The vessel was designed originally for reciprocating engines and the intention to have oil engines installed was an after-thought. The vessel is thus somewhat fuller aft than would be the case if firstly designed for motor propulsion, but advantage is taken of this to provide accommodation for the oil tanks. The leading particulars of the vessel are as follows :—

Length B.P.	149′ 0″	
Breadth mld.	25′ 6″	
Depth mld.	11′ 0″	
Load Draught	9′ 10″	mean
L.C.B.	1′ 6″	ford

The motor is the four-cylinder Bolinder direct reversible engine, using crude oil, having a B.H.P. of 350 at 250 R.P.M. and capable of giving a sea speed of fully $8\frac{1}{2}$ knots.

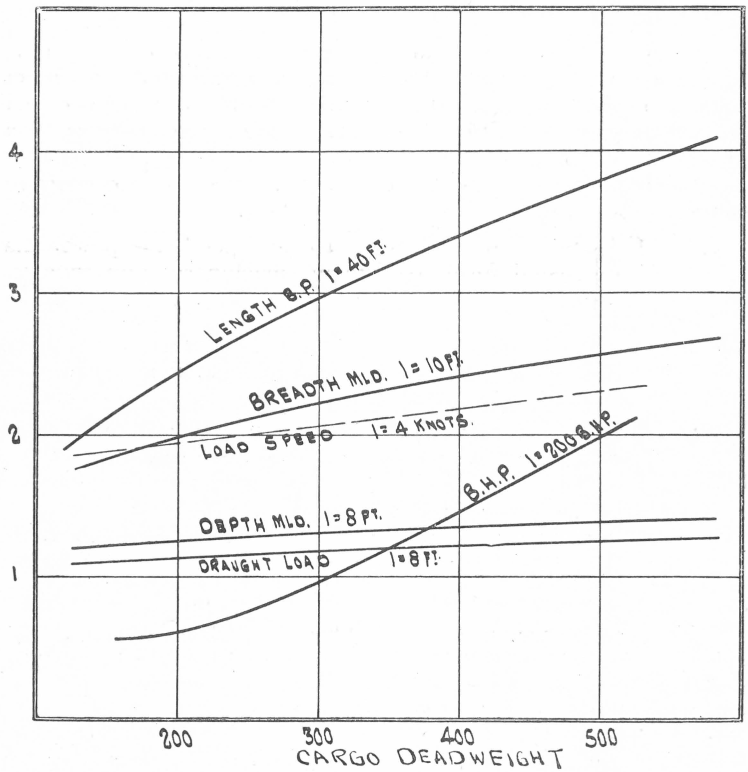

FIG. 123. CURVES FOR APPROXIMATE DIMENSIONS OF MOTOR COASTERS.

One of the reasons for substituting an oil engine for steam was the increased gain in carrying capacity. As originally designed for steam, the deadweight was calculated at 420 tons; the substituting of an oil engine raises the deadweight to 500 tons.

In Fig. 123, curves are given, on a base of cargo deadweight, for the determination of the approximate dimensions, etc., of motor coasters, while in Fig. 124, speed and power curves are given for motor coasters.

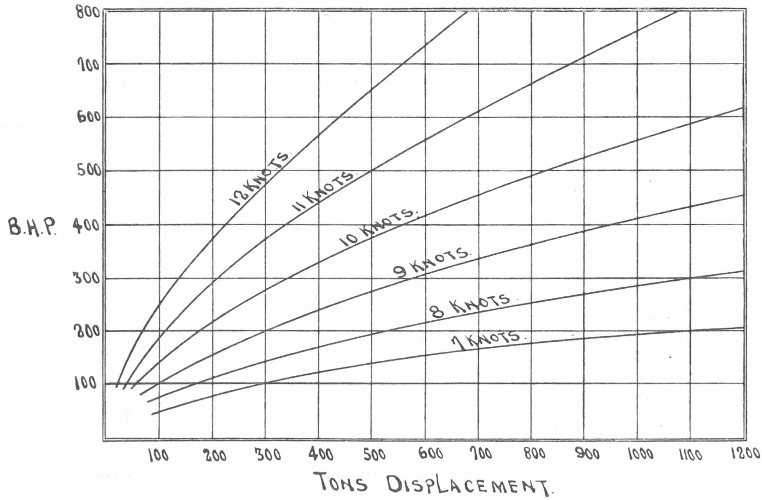

FIG. 124. SPEED AND COWER CURVES. MOTOR COASTERS.

The additional cargo capacity available in a motor coaster, compared with one equipped with steam machinery, is an important item. This increased capacity amounts in some cases to about 15%, and the comparison for a 790 ton deadweight coaster is given below. The particulars of the steam vessel are as follows:—

Length O.A.,	180′ 0″,	B.P.		174′	6″
Breadth mld.	...	...	...	28′	6″
Depth mld.	...	...	...	13′	0″ to main deck
Draught load	...	...	...	12′	8″
I.H.P. ...	...	...	...	660	

The machinery consists of a triple expansion engine with cylinders 14, 23, and 38 ins. in diameter with a stroke of 27 in. and a single ended boiler 14′ 0″ in diameter and 10′ 6″ long.

The motor vessel is taken as fitted with a six cylinder British Kromhout oil engine of 650 I.H.P.

Figs. 125 and 126 show the comparative space occupied by the Kromhout engine and the triple expansion steam engine. The blocks have been kindly supplied by Messrs. Perman & Co., Ltd.

The actual gain in cargo deadweight, brought about by the lighter Kromhout engine and the elimination of the boiler, is 115 tons, and the additional cubic capacity 4,850 c. ft.

These results are obtained as follows :—

Weight of steam machinery ...	102 tons.	
Weight of oil engine and auxiliaries	47 ,,	
Saving	55 ,,	55 tons.
Weight of bunker coal (Same	70 ,,	
,, ,, ,, oil Radius)	20 ,,	
Saving	50 ,,	50 ,,
Feed Water dispensed with ...		22 ,,
		127 tons.

Deduct donkey boiler full of water	5 tons.	
,, ,, ,, bunkers	2 ,,	
,, ,, ,, feed water	5 ,,	
	12	127 tons.
		12 ,,
Total saving		115 tons.

which is the increased weight of cargo that can be carried.

The total deadweight in steam vessel is ...		790 tons.
Deduct coal	70 tons	
,, feed water	22 ,,	
,, stores, say	10 ,,	
		102 tons.
Actual cargo carried with steam vessel		688 tons.
With oil engine the actual cargo carried is increased by		115 ,,
To		803 tons.

Thus the cargo deadweight is increased from 688 tons to 803 tons, $16\frac{1}{2}\%$, and since the cubic capacity of vessel is increased by about 4,580 cu. ft., there is ample space to carry the increased cargo.

The total deadweight of motor vessel is made up as follows :—

Cargo dwt.	803 tons.
Bunker oil	20 ,,
Donkey boiler feed water	2 ,,
Donkey boiler bunkers	5 ,,
Stores	10 ,,
Total	840 tons.

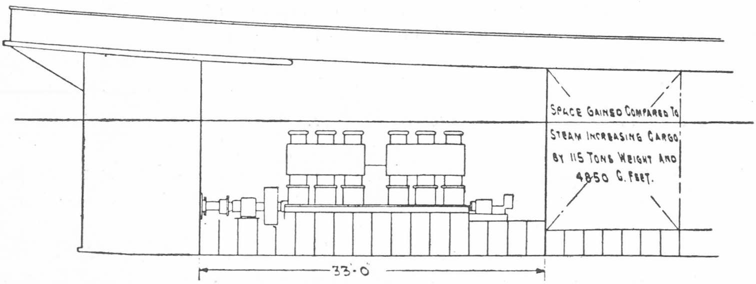

FIG. 125.

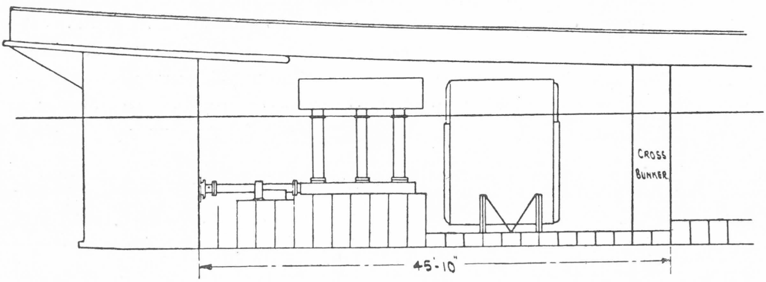

FIG. 126.

CHAPTER 12.

OIL TANKERS.

Within recent years the necessity for vessels capable of transporting oil in bulk has increased considerably, and although they were unknown many years ago, the improvements and advancements in their design and construction have rendered possible a highly efficient and important craft. A considerable saving in expenses and a speedy dispatch are effected when the oil from

large tankers can be pumped directly into smaller river boats. In many cases instead of having to pump the oil into large containers ashore, and from thence into barrels for dispatch, the oil can be delivered direct to the consignees' wharf. On account of the considerable saving of space, and the ease with which the fuel may be obtained, tankers, within the last few years, have been installed with the internal combustion engine.

Before discussing the features of this class of vessel, it may be advisable to mention one or two outstanding characteristics of the cargo they carry, as, unlike most vessels, the nature of oil requires very extensive modifications in the design and construction of vessels in which it is intended to carry the oil in bulk. The considerations which immediately present themselves to the Naval Architect are :—

1. That if the temperature of oil be increased it is subject to expansion, and *vice versa*.
2. That gases which arise from oils, especially from petrol, benzine, etc., become highly explosive when combined with the atmosphere.
3. That the oil exerts an equal pressure against the surface with which it comes into contact. With ordinary cargo, the weight bears directly upon the floors.
4. That when a vessel rolls the liquid is open to free movement, thus, unless the stability of the vessel is assured, danger may result should rough weather be encountered, or should the vessel heel when only partially loaded.
5. That in pitching and tossing, the inertia of the fluid increases, to a considerable extent, the pressure upon the transverse bulkheads.

As far as the design is concerned it may be easily deduced from the above that stability is one of the greatest considerations. It is for that reason that tankers call for certain characteristics. Both transverse and longitudinal stability must be assured, although it must be borne in mind that it is essential that the vessel should be easy in a seaway. Any stiffness, causing sudden movements will cause the fluid to wash from side to side, thus exerting undue stresses upon the shell plating, etc.

The smaller of the tankers may be divided into three classes, as given below, and it may be said that, roughly, three types of hulls are required for each.

Type I. Tankers employed upon estuaries and on exposed waters. Occasionally these vessels may be required to serve near coastal towns.

Type II. Tankers employed upon rivers, etc.

Type III. Tankers employed upon restricted rivers, and on "navigations" and canals.

Fig. 127 shows the sheer draught of a vessel working under Type I., and may serve as a typical example of her class. It will

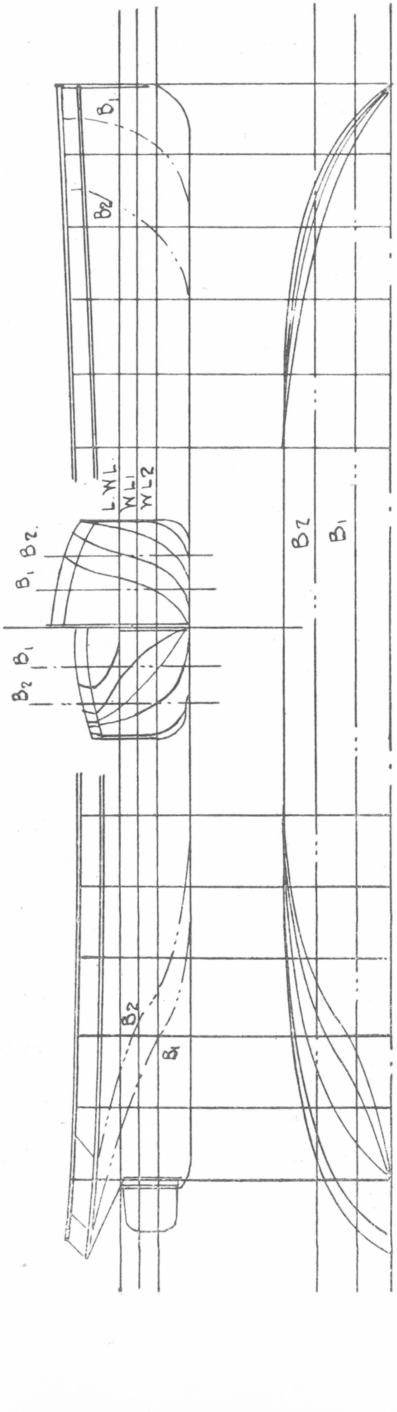

FIG. 127. SHEER DRAUGHT OIL TANKER.

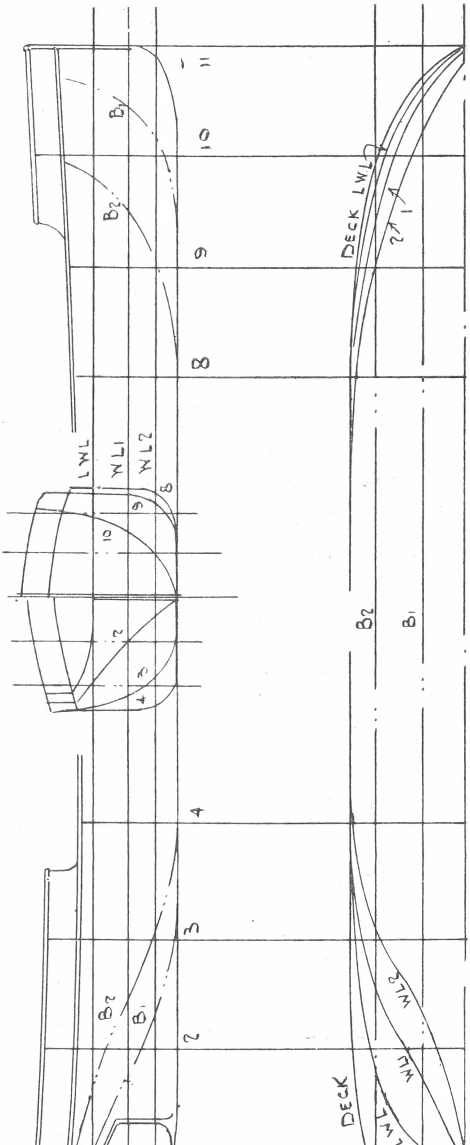

FIG. 128. SHEER DRAUGHT OIL TANKER.

be noticed that the lines show a hull not unlike the coasting vessel. A block coefficient between 0.60 and 0.70 with a prismatic coefficient between 0.65 and 0.75 are normal. A comparatively full entrance, with considerable flare to the sections, are characteristics of the fore body, while the midship section shows a solid, stable contour, with little rise of floor and a substantial radius of bilge. The parallel middle body is comparatively long, and the after lines show that care has been taken to ensure a clear flow of water to the propeller and to provide sufficient buoyancy. The sections, while being fine at their lower part, flare out towards the deck, and it is to be noticed that while these requirements are being fulfilled, sight has not been lost of the fact that the straighter the sections the cheaper will be the construction, thus as little curvature as possible has been given to the sections throughout.

Fig. 128 gives the sheer draught of a smaller vessel, working under Type II. conditions. Owing to the length-depth ratio, due to the restrictions on the draught, the lines are not compatible. Full U sections are continued from the stem to the amidships, no flare being necessary, sufficient protection being afforded by the plating of the forecastle bulwarks. Some relief is given by the after lines, however, for we find that they are as fine as possible. While with vessels of this class, for efficiency of propulsion, etc., it is desirable to have the after body as fine as possible, it must be remembered that these vessels are frequently aground, and if insufficient buoyancy is given to the after part, the fore body becoming water borne first, will tend to lift the vessel on the sternframe, the result being that severe stresses will be set up, and these may result in damage.

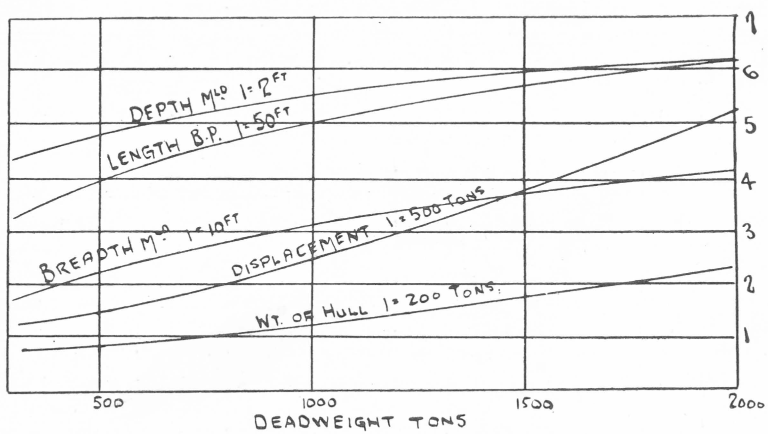

FIG. 129. CURVES OF DIMENSIONS, WEIGHTS, ETC., OIL TANKERS.

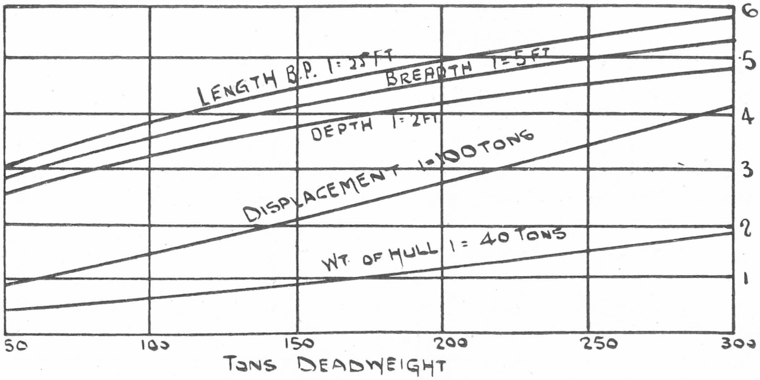

FIG. 130. CURVES OF DIMENSIONS, WEIGHTS, ETC., OIL TANKERS.

Generally the designing of tankers under Type I. closely resembles that of the coaster or large river barge, and those under Types II. and III. the smaller river barges and lighters, and for further information the reader is referred to the chapters dealing with such vessels.

Curves giving the approximate dimensions, weights, and principal particulars, etc., are given in Figs. 129 and 130. Fig. 129 deals with large tankers from 300 to 2,000 tons deadweight carrying capacity, and the other set of curves are for vessels from 50 to 300 tons deadweight. Of course these curves are subject to local conditions, and the reader should acquaint himself with local conditions before finally determining the principal dimensions.

Fig. 131 shows the general arrangement of a typical tanker, and while as far as crew accommodation and main engine arrangements are concerned the lay-out resembles that of a coaster, but the arrangements of the holds are, however, unique to the class. The principal dimensions of this vessel are :—

Length, between perpendiculars	...	180′ 0″
Breadth, moulded	...	36′ 0″
Depth, moulded	...	15′ 3″
Draught, maximum, aft ...	...	12′ 0″

The holds, which are divided one from the other by cofferdams, are in the form of large tanks, into which the oil may be pumped. A cofferdam is fitted between the after hold and the engine room or boiler room, and between the forward hold and the crews' quarters. These cofferdams, which are fitted at about two frame spaces apart, are oil-tight bulkheads which extend from the floors to the underside of the deck, and prevent oil from finding its way into the engine room or into another tank. These are dealt with fully later.

The general arrangement of a smaller boat is shown in Fig. 132, the sheer draught of which vessel is given in Fig. 128.

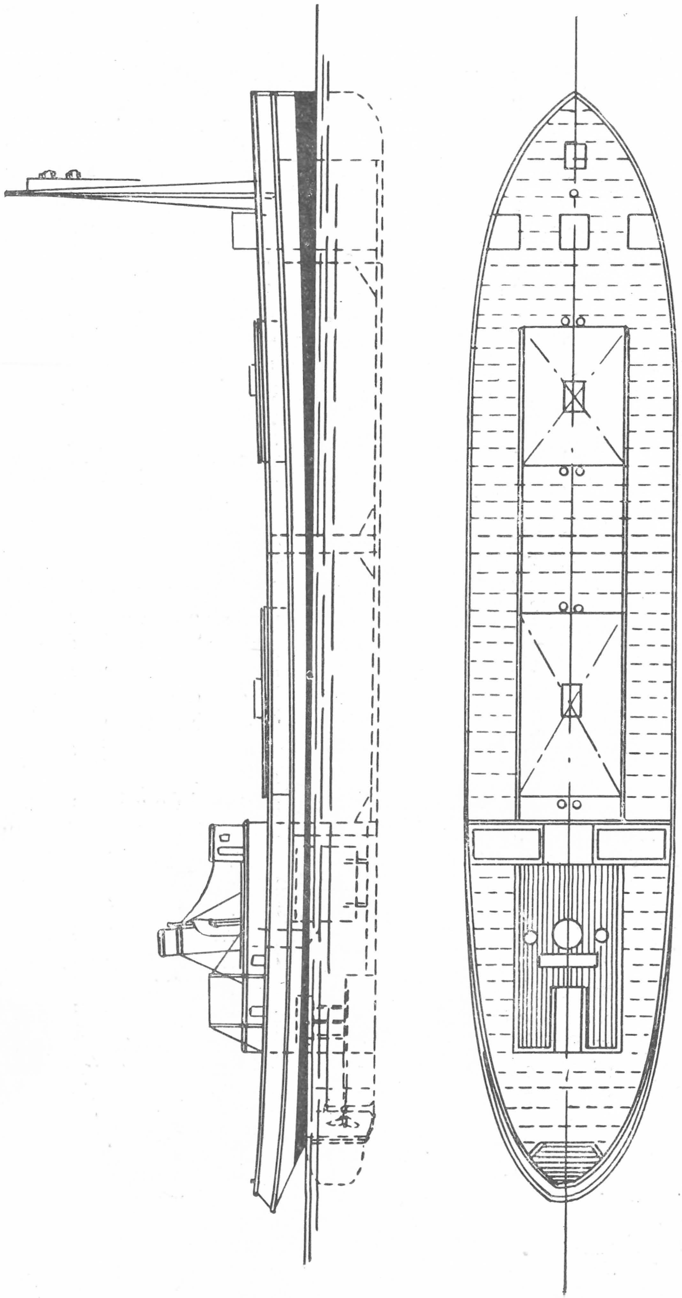

FIG. 131. GENERAL ARRANGEMENT OIL TANKER.

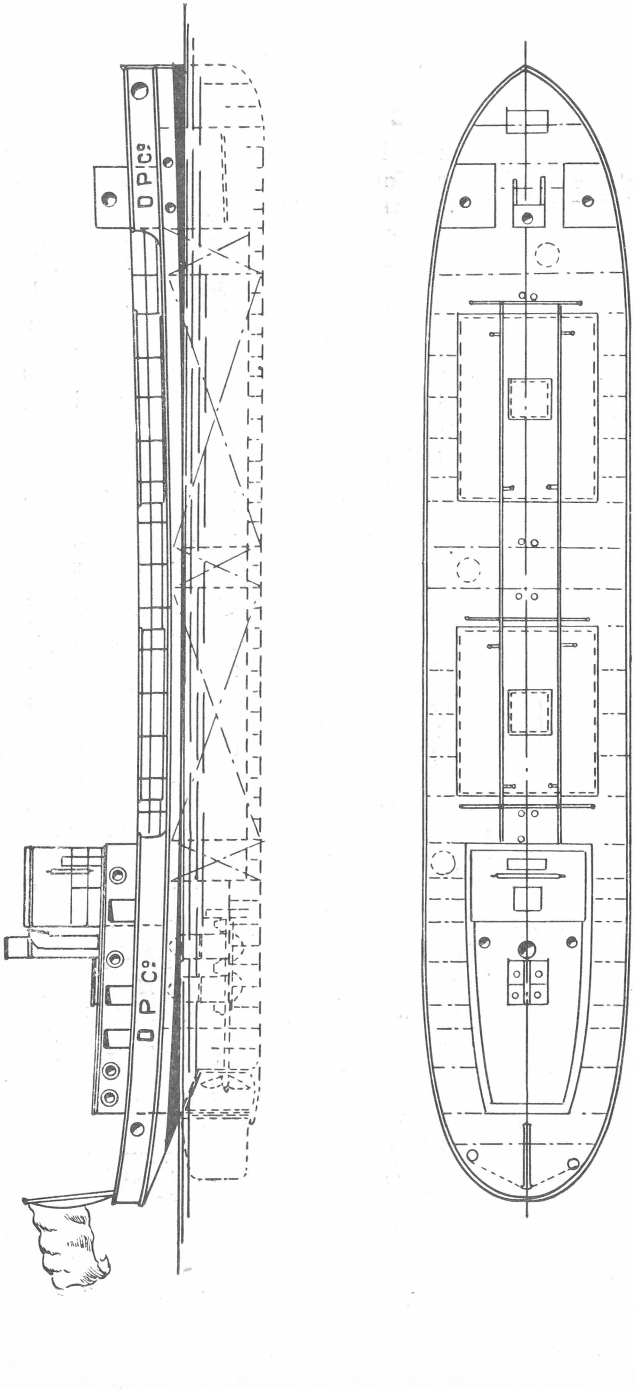

Fig. 132. General Arrangement Oil Tanker.

Her principal dimensions are :—

Length between perpendiculars	...	100′ 0″
Breadth, moulded	...	20′ 0″
Depth, moulded	...	8′ 6″
Draught, aft, maximum ...	...	7′ 6″

With this vessel the crew are quartered aft and the fore peak is used as two cabins, for the Captain and Engineer. Two large tanks are fitted in the length of the vessel, and all the pumping machinery is housed in the casing at the forward end of the engine room casing, this method being employed to reduce the length of the engine room. The main hatches are as large as possible, to increase the carrying capacity, and large expansion hatches are adopted above for reasons previously mentioned, and to be dealt with in detail later.

The construction and arrangement of an oil barge is given and discussed in Chapter 5.

When oil is carried in bulk, it extends to the inside of the shell plating, and as previously mentioned, is unlike ordinary cargo insomuch that a pressure is exerted in every direction. This brings about special considerations in the construction of tankers. It is necessary in order to provide sufficient strength, to fit shell plating of substantial thickness, about 5 per cent. above normal, and not to reduce the thickness except with large vessels over 1,000 tons displacement, until the holds be passed. The keel is always of the flat plate type, and a rubbing strake or a doubling piece should be fitted on the outside as a precaution against the keel becoming damaged in the event of the vessel taking the ground. The bottom plating and the bilge plating are kept unusually heavy so that the bottom is suitably stiffened, and besides the reason given above, the side plating is also heavy in order that it may withstand the rough usage to which it is frequently put when coming alongside. The floors should be of sufficient depth, and if the length-breadth ratio be small, should be increased in order that the bottom may be suitably stiffened.

Keelsons, composed of double angles, placed back to back, should be carried as far forward and aft as practicable, and should be of sufficient number to warrant the effective stiffening of the floors, and sufficient longitudinal strength. Side keelsons with the vertical plate are necessary in large vessels as they prevent the oil from washing from side to side. Limber holes, however, must be cut in order that the oil may run freely to the pump suctions. Side stringers are fitted as with normal vessels. Keelsons and stringers are sometimes stopped at the bulkheads so as to make the construction cheaper, but when this method is adopted, the greatest care must be taken to ensure that the continuity of the strength is not lost. For this reason large plate brackets are fitted on each side of the bulkhead connected to the stringers or keelsons, as the case may be. In many cases,

however, the keelsons and stringers are continued through the bulkheads, a rough hole being cut in the latter to allow them to pass. Oil-tightness is effected by fitting carefully smithed collars made up of angles, and afterwards caulked.

The bulkhead arrangement is, perhaps, the most important consideration in the construction of tankers. The provision of ample transverse strength is in itself important, but with bulkheads dividing off large quantities of fluid, the stresses which they have to withstand are considerably in excess of those of a vessel carrying ordinary cargo. The bulkhead plating, therefore, is often over 10 per cent. greater in thickness than would otherwise be required, and the spacing of the bulkheads themselves is much reduced. The larger the tank, the greater will be the pressure upon the bulkhead, especially when the vessel is pitching and tossing, and for this reason the bulkheads should be as near together as practicable. The plating is generally arranged horizontally, and the laps are sometimes flanged to form stiffeners. Vertical stiffeners of the same spacing as the ordinary frames are always fitted, the necessary brackets, being supplied for connection to the underside of the deck.

It is evident that the riveting of the bulkheads should be as efficient as possible, and great care must always be taken both in regard to the bulkhead and shell plating, that all rivets be tight. Loose rivets must never be caulked, but new ones fitted, and blind holes should be rimed fair, the use of the drift punch being rigidly forbidden. For oil-tight work, the plug head or the pan head rivet with swollen neck should be used, since experience has shown that these are preferably for such work. Although the spacing of the rivets on the butts and landings of the bulkhead plating is kept normal, the bulkhead frame rivets are spaced somewhat closer together than usually.

The cofferdams, which have been previously mentioned, are spaced usually about two frame spaces apart, and the bulkhead at each end must be oil tight, and suitably stiffened. The stiffeners generally take the form of diaphragm plates fitted across and attached to the bulkheads by angle bars. The spacing of the diaphragms is a matter of judgment and calculation, but care must be taken to ensure that the stiffening is sufficient to withstand a normal expected pressure.

If the length and breadth of a vessel warrants it, a longitudinal bulkhead, extending from the floors to the under side of the deck, must be fitted. Besides affording considerable longitudinal strength, these bulkheads assist materially in reducing the pressure on the plating, and also prevent a vessel from heeling dangerously when being filled. Of course a vessel should never proceed to sea with a tank only partially full, since this would be courting disaster, but with small river a tank is often only partially full, and the bulkheads play an important part in

preventing the oil from washing from side to side, should the vessel roll a little. With longitudinal bulkheads the plating is arranged horizontally, as with the transverse bulkheads, and is stiffened by vertical angles, etc. The stiffeners are again of the same spacing as the frames, and are bracketed to the floors and side riveted.

The next consideration in the construction is that of the hatches. These are comparatively deep, in river craft often over 3 ft. in height. The hatch covering is usually iron or steel plating, of somewhat less thickness than the deck plating, and stiffened on the inside by angles of suitable size. The plating is connected to the hatch coamings by an angle, fitted inside, and protection is given by a half-round or convex iron bar which is continued all round the hatch at the top of the coamings. The hatch forms an expansion trunk, from which all gases may be drawn off. In the centre of the hatches a smaller hatch is situated which in all respects is the same as the main hatch except that a suitable man-hole is fitted to allow for entrance into the hold. Sometimes this hatch, which must be oil tight, is of such dimensions that it is in itself a man-hole, when a suitable oil tight door is fitted. In some large boats, the tween decks form the expansion trunks, when it is only necessary to fit oil tight hatches on deck. On the other hand in some small vessels the small hatch is of sufficient size to form the expansion trunk, when the larger hatches previously mentioned are unnecessary, and the small hatches may be placed directly on the deck.

For estimating purposes, etc., the following table gives the approximate cubical expansion (real) of liquids per degrees between 0 deg. C and 40 deg. C (32 deg. F and 104 deg. F) :—

Water	0.00026
Turpentine	0.00039
Kerosine	0.00042
Paraffin	0.00042
Fleizoel (Fuel Oil)	0.00044
Leuchtoel	0.00045
Gasoline	0.00048
Gas Oil	0.00051
Benzine	0.00053
Essence	0.00054
Naphtha	0.00055
Petroleum	0.00099
Petroleum Spirit	0.00103

The last, but by no means an unimportant consideration in the construction of tankers, is that of the provision of an efficient ventilating system. All compartments, including the cofferdams, must be well ventilated, notice being taken of the fact that the gases which are emitted from the oils are of greater specific gravity than the atmosphere, and are thus liable to hang around the lower parts of the tanks. Perforated pipes are often led from the coffer-

dams, to the decks, so that owing to the circulation of air, the gases are carried up to the ventilators on the deck. In the holds mechanical methods of ventilating are resorted to, and in the case of steam vessels, special steam ejectors are fitted to force the gases from the holds. These cannot be used with oil driven ships unless a donkey boiler be fitted, so it is usual to instal suction fans to draw gases, from the tanks. At least one down-take and one up-take ventilator should be fitted to each compartment, and if the size of the compartment warrants it, ventilators must be fitted at each end, and in the length, but it is advisable always to work the ventilators in pairs, so that the circulation will be constant.

Excepting the pumping arrangements, the pipes of which are, in small vessels, on deck, the various deck fittings closely resemble those of a coaster or large barge. The windlass forward, which is generally hand driven, is the only mechanical contrivance. A mast is sometimes fitted on the forecastle deck to carry lamps and flags etc., but this is more or less a pole fitted in a tabernacle.

The pumping machinery is, in size, greatly governed by the rapidity with which it is required to load or discharge the cargo. Many tankers employed on rivers have no pumping machinery other than that required for the engines, the vessel being loaded and discharged by either pumps on the large tanker or by pumps ashore. Others, however, have a complete pumping outfit of their own, which thus renders them entirely independent of outside help. For many reasons it is desirable to fit all the pumping machinery on deck, in some suitable housing, but this is not always possible. Sometimes two or more separate pumps are placed forward amidships and aft, each serving their respective holds, but with smaller vessels the engine is generally situated aft, and directly coupled with the pump.

The majority of recent tankers have been installed with the centrifugal pumps, directly coupled with a motor of comparatively low horse power. Near the engine and pump are fitted suction and delivery boxes, which serve the respective holds. The pump-suctions are carried down into the holds as far as possible, and scrum boxes are fitted to the end of the pipes to prevent any foreign body choking the pumps. Large limber holes are cut in floors and keelsons to allow a clear flow of oil to the pump suctions.

Like the suction boxes, the delivery boxes have connections so that pipes may be led ashore or aboard another vessel as the case may be. A large locker for storing the flexible tubing is usually situated near. The delivery pipes to the tanks should end reasonably low in the hold, and the entry of all pipes through the hatches, should be rendered water and oil tight, so that no water may find its way in, and no oil find its way out of the tanks. The pipes, the leads of which should be free from unnecessary bends, must be of substantial thickness. Where possible

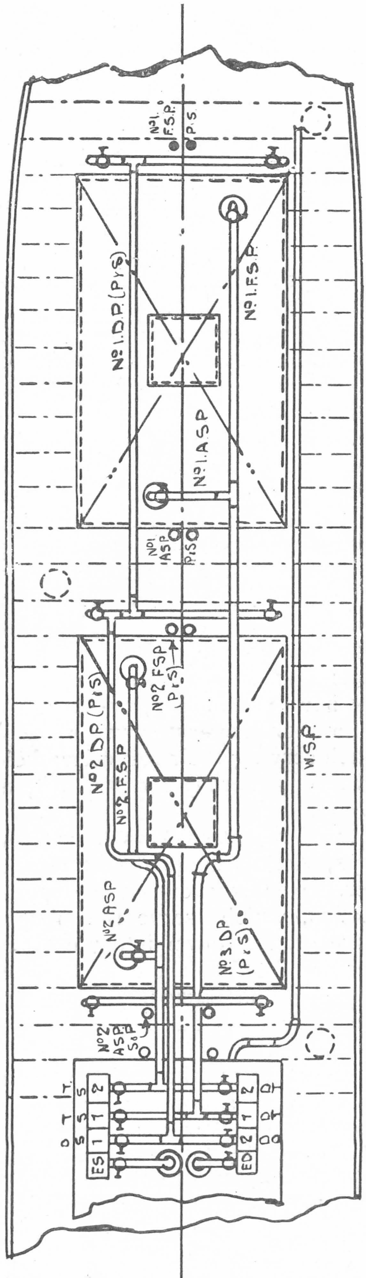

FIG. 133. DECK PUMPING ARRANGEMENT.

they are on the tops of the hatches or fitted in the corner made at the hatch coamings and the deck, but wherever necessary some suitable protection, such as an arched plate, must be adopted.

Fig. 133 shows the deck pumping arrangement of a large oil barge, and the various fittings, leads, etc., can be easily seen.

Fig. 134 gives a photograph of the M.V. "Pando," one of a large fleet of oil tankers which were comparatively recently built for foreign service. The hulls were built by Messrs. J. S. White & Co., Ltd., and the vessels are installed with the Kromhout engines. The propelling machinery develops 180 B.H.P. at 320 R.M.P., and the pumping engine gives 80 B.H.P. at 350 R.P.M. The pumps, which are coupled direct, are capable of dealing with the complete cargo—500 tons—in two hours.

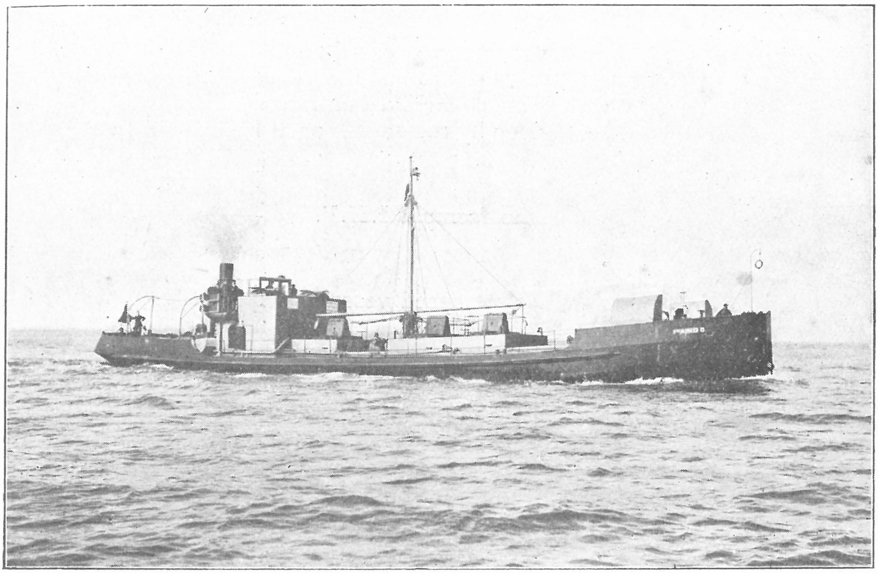

Fig. 134.

As a general rule it may be said that all the vessels such that we are treating in this chapter have their engines installed as far aft as practicable, since this method, besides making a distinctive economy in space, considerably reduces the cost of, and simplifies, the construction. Fig. 135 gives the speed and power curves suitable for tankers. For reasons previously mentioned oil engines are usually installed, and therefore B.H.P. is given instead of I.H.P., but if the latter is required, an addition of about 10 per cent. should give suitable results. The curves are

based upon the Admiralty coefficient formula, I.H.P. $= \dfrac{D^{2/3} \times V^3}{C}$

Where V = speed in knots,
D = displacement in tons.

The coefficient c varies between 130 and 150, according to the vessel, and it may be noted that there is a sharp bend in the curve of coefficients when the speed-length ratio rises above 0.8. That is, proportionately greater power is absorbed and lost in wave making resistances when the speed of the vessel exceeds $0.8 \dfrac{V}{\sqrt{L}}$

Greater economy is effected therefore, when the vessel is run below this speed, and since there are but few requirements in this direction, especially with vessels employed on rivers, it is advisable not to increase the speed given by the above, or at least, fix a limit at, say, 0.85. Many use the formula I.H.P. $= \dfrac{S \times V^3}{20{,}000}$ which gives reliable results with slow speed vessels. Here S is given

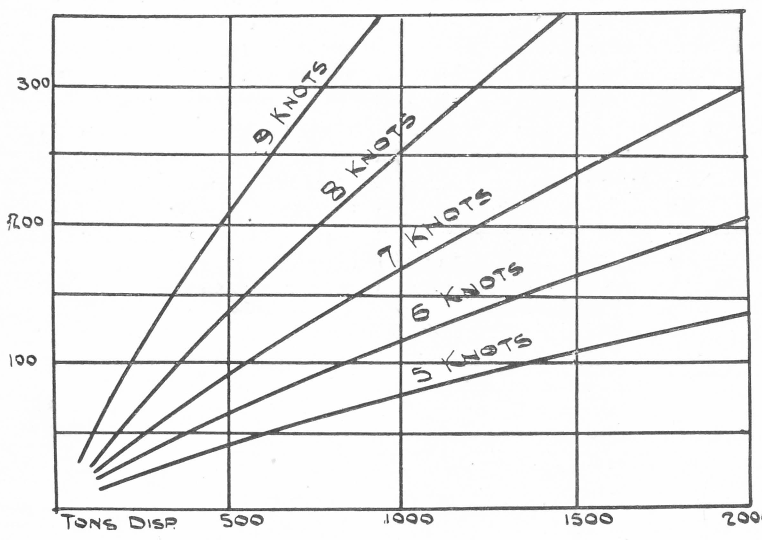

FIG. 135. SPEED POWER CURVES, OIL TANKERS.

by the wetted surface, and may be estimated by :—

$$S = 14.8 \sqrt{W \times L}$$

Where L = length between perpendiculars, in feet.
W = displacement in tons.

Not many difficulties present themselves in the propeller considerations. Like all screws driven by oil engines, the pitch-diameter ratio varies between 0.5 and 0.8, the greater the speed of the vessel, of course, the greater the ratio. The ratio of the developed area to the disc area, however, remains fairly constant at 0.33, and the disposition of the area should be such that the greatest width of blade be about a two-thirds diameter.

Before dismissing this chapter dealing with river tankers, mention may be made of an Act passed in Parliament quite recently and known as the Oil in Navigable Waters Act, 1922. Briefly, this Act makes it unlawful to discharge oil or oily water within the three miles limit. This is to protect rivers, etc., from pollution; it nevertheless renders many difficulties as regards to the cleaning of the hold, and the discharging of bilge water from tankers. Messrs. Smiths' Dock Company have, however, met the situation. They have built a 250 ton barge, which by means of conical filters and separators is capable of separating oil from bilge water. The barge may be towed alongside a tanker, and the bilge water pumped into the containers, which after passing through the various contrivances, is discharged overboard, the oil being retained in suitable tanks. Besides answering the requirements of the law, the barge holds other advantages, insomuch that the otherwise lost oil can be used. Since 180-200 tons of ballast water can be dealt with in one hour, it shows that the working is very quick, and as an example of the economy effected, of 2,000 tons of ballast water which was dealt with in little over 10 hours, over 60 tons of oil was retained. The advantage of this will be readily seen by all interested in this class of vessel, and no doubt after the highly satisfactory results obtained from this first experimental craft, several other oil separating barges will soon be on service in the many ports around our coast.

CHAPTER 13.

PILOT BOATS.

For many years after the advent of the steam engine, as used for marine purposes, the various pilotage services around our coast, and those of continental countries persisted in the well known and historical pilot cutter, and it has been only within very recent years that the rough old "sea-salts" in this particular employ have been converted to adopting the newer methods of ship propulsion. As late as 1916 several of the small, but fast sailing cutters were still in use on the Bristol Channel, but most have now been either sold or scrapped, and more modern boats substituted. The service of pilot boats is somewhat peculiar. While they are always of somewhat small dimensions, they nevertheless are expected to encounter weather that an ordinary vessel of their size could not legitimately endure. Seldom in port, and then only to obtain stores and provisions, these vessels are always steaming around their circuit either dropping or picking up pilots who serve the large deep-water vessels that are coming into or leaving port.

It may be logically supposed that these vessels require the greatest considerations in their design, since speed as well as safety are of importance—two requirements which are inversely proportionate, and which are difficult to obtain in comparison with vessels of larger size. One or two points in favour, however, are that there are no unnecessary reductions nor modifications on the various ratios of length and breadth, and in fact, pilot boats of extreme proportions are practically unknown. Having this, the Naval Architect has good scope for producing a seaworthy craft; thus we find that with a comparative light weight of hull, and a small value for the block coefficient, the shape of the under water body while being fine, is nevertheless of a good, stable shape.

A very fine entrance, with the load water line practically straight for about one-fifth or one-sixth of the water line length, is typical of modern vessels of this type. While the water line is fine, it is inadvisable to introduce hollow water lines forward, at least not until the fore foot be reached, since the provision of a reasonable amount of buoyancy is specially needed forward, besides the incompatibility of this type of under water body in regard to resistance. The sections usually show a comparatively full flare, in order that seas will be kept reasonably clear from the deck, etc. The lower part of the sections are of U form, although the rise of floor from the midship section may tend to give a sharp rise and a tendency to a V shaped section. It should be borne in mind,

therefore, that while fine sections are desirable, that buoyancy and stability which can only be obtained from the U section, must be interwoven or superimposed upon the finer V sections, at least as far as the forward underwater body is concerned. The midship section is usually somewhat fine, the coefficient of fineness generally being between 0.50 and 0.75. This very fine coefficient is rendered possible by giving a large rise of floor and a large radius of bilge, and in some foreign pilot boats working in very deep water, and with an abnormally large rise of floor and radius of bilge, the coefficient is below 0.42, but this besides being unnecessary, produces a most unserviceable form of hull which renders the machinery being fitted high in the vessel, and reducing the floor space of the accommodation, that in reality the form of hull is quite incongruent with sea-worthiness and stability, since all the interior work tends to bring the Centre of Gravity relatively high. Therefore, while keeping a practicable rise of floor and a reasonable radius of bilge, the sides of the vessel amidships need not be kept perpendicular. In fact, a reasonable curve is given which produces a little tumble home of 2 to 3 inches. The tumble home is generally continued aft, while the lower water lines are again brought fine both for the sake of resistance and efficiency of propulsion. The upper parts of the sections reserve a considerable amount of buoyancy, since it is important that vessels of this type should ride well in a following sea.

Many of the first steam pilot boats had the cut-water stem, so familiar with the early steam yachts, but for many reasons this has been superseded by the straight stem. The type of the stern has received special consideration by many. The first steam pilot vessels had the usual counter stern, and this type apparently it seems will stay. The cruiser and canoe type of stern has been suggested and tried, but these, especially the former, do not offer much protection from seas, besides being rather more difficult to build in steel or iron. A fairly long counter suitably supported, and the bulwark rail falling outwards, forms a good protection from following seas, besides having many other advantages, and it is for these reasons that the majority of British pilot boats have preserved the first type of stern.

The lowest point of sheer is usually a little abaft amidships, about 1/20 to 1/10th of the B.P. length, and in all cases a reasonable freeboard is allowed. The sheer forward generally shows a little flatness, but forward is always given a good sweep up which tends to keep the forward deck dry, and also allows the shaping of the forward sections. A small curve of sheer is given aft, sufficient to render the after deck reasonably dry.

The stability, as previously mentioned, is important. Since the Centre of Gravity comes fairly low in the vessel and the lines of the boat are fine, filling out, of course, to the water line, there is a decided tendency to "stiffness." This is particularly

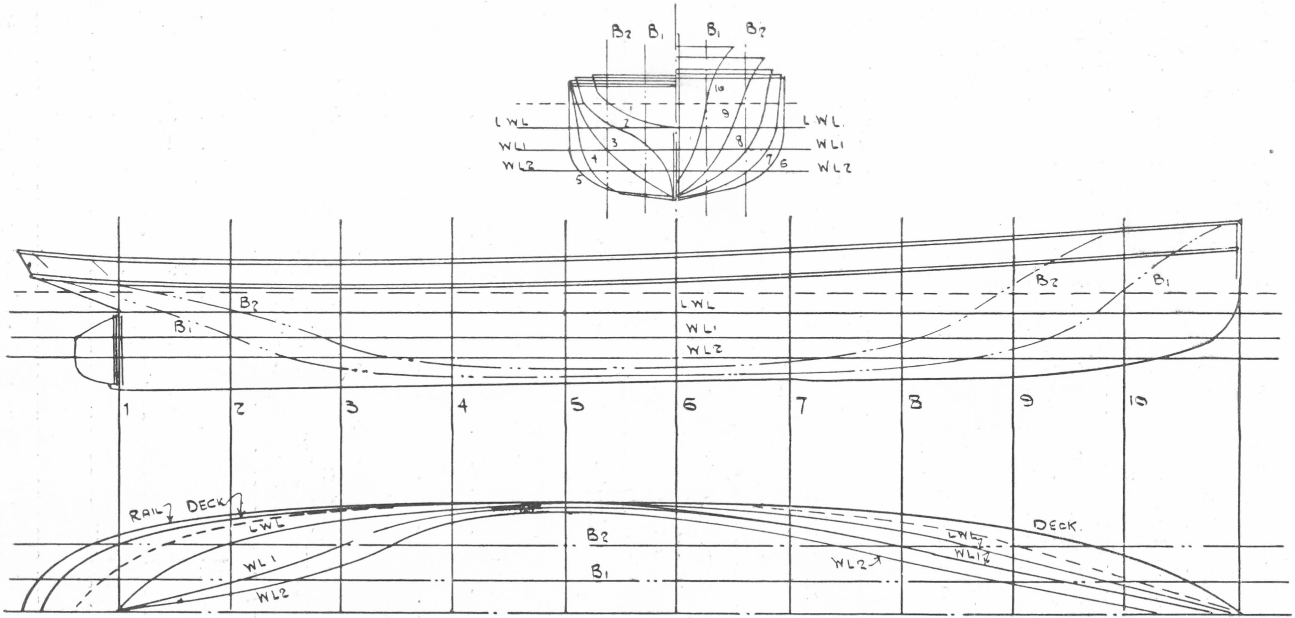

FIG. 136. SHEER DRAUGHT PILOT BOAT.

undesirable, since a reasonable amount of comfort is expected by the crew and pilots, and nothing can add to the unpleasantness of a long sojourn on the water, especially if the weather be bad, than that obtained in a boat, which feeling every motion of the wave, rolls violently from side to side. An exceptionally easy boat may give equally undesirable results, and, therefore, some happy medium must be arrived at. If a reasonable value for the block coefficient, say about 0.5 to 0.55, and the area of the load water plane kept within compatible limits, a metacentric height of between 15 and 24 inches should be obtained, and as a limit, it may be said that it would be inadvisable to exceed, say 30 ins. for this value. The righting lever, G.Z., should never be abnormally greater than the moment given by the weight of the vessel at a lever of 1 foot, and in all cases it should be kept within practical limits.

Fig. 136 shows the sheer draught of an English pilot vessel built for service in the channel. The foregoing notes in reference to the shape of hull will be noticed. The forward buttock or bow lines show the characteristic hollow, while their filling shows a reasonably good "belly." The after buttocks again show the hollow, and afterwards run fairly into the counter. It is interesting to note the filling out of the after sections directly above the water line, and which is clearly seen in the half-breadth plan. The dotted waterlines, *i.e.*, those above the load water line, are all rounded, but the load, which is a fairing line, leads to fine, hollow water lines of the under water body. Further particulars of this boat are given later.

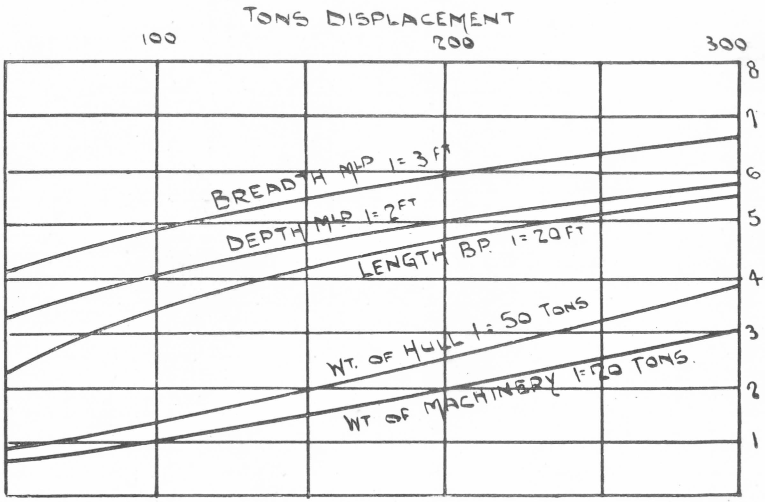

FIG. 137. CURVES OF DIMENSIONS, WEIGHTS, ETC., PILOT BOATS

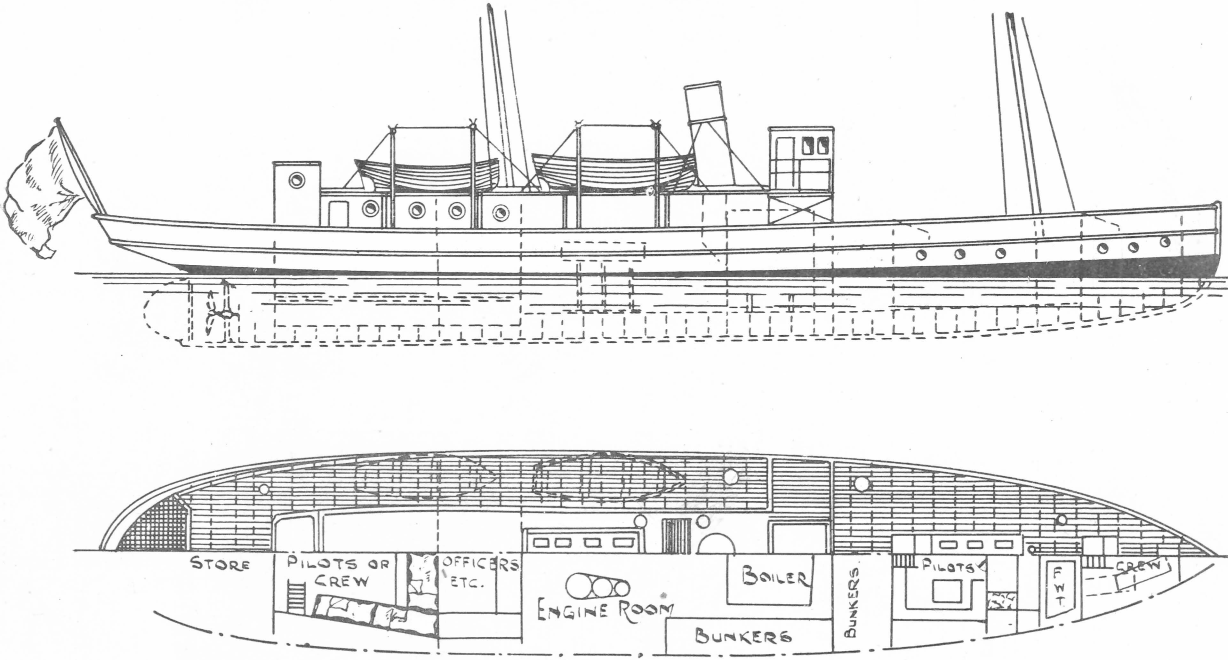

FIG. 138. GENERAL ARRANGEMENT PILOT BOATS.

Curves giving the principal dimensions, weights, etc., of pilot vessels, have been prepared, and are shown in Fig. 137. These curves include boats between 40 and 110 feet in length, and it is seldom that this last figure is exceeded. Restrictions are generally imposed upon the draughts, and therefore no draughts are shown.

The general arrangement of the vessel previously mentioned is given below, Fig. 138. Her principal dimensions are :—

Length, between perpendiculars ...	100′ 0″
Breadth, moulded	19′ 6″
Depth, moulded	8′ 6″
Draught, maximum, aft	7′ 0″
Indicated Horse Power	250
Speed in Knots, on trials	11

The accommodation and arrangements are more or less unique to the class. The engines are installed immediately abaft amidships, while directly forward a return boiler is fitted. Two side bunkers alongside the boiler, and one large athwartship bunker at the forward side of the bulkhead hold sufficient fuel for 45 days' continual steaming, so that calls at port for the purpose of taking in coal are not unnecessarily frequent. The crew are quartered in the forward immediately abaft the small peak, which is allowed for the free run of chains, etc., to the locker below. Aft of the forecastle bulkhead are two large fresh water tanks, which hold 150 tons of water. They are in an enclosed space, abaft of which is situated a mess room and two cabins, for the use of pilots. In the after end of the vessel are fitted up several bunks, for pilots, forward of which are the Captain's and Engineer's cabins, with saloon. On deck, at the after end of the casing, are a w.c. and galley, while at the forward end of the casing is the bridge, which extends the full breadth of the vessel. Four boats, one dinghy, one working boat, and two long boats for the use of the pilots, are carried under davits, on the casing, special launch ways, composed of tee-bars of light scantlings, are used to facilitate launching when at sea.

Fig. 139 shows the general arrangement for a somewhat unusual type of pilot boat. It was built abroad for foreign service, and while in many respects differing from the more conventional type, the general lay-out and design shows a comparatively seaworthy craft. Smaller than the other vessel, her principal dimensions are :—

Length, overall	70′ 0″
Breadth, moulded	15′ 0″
Depth, moulded	8′ 3″
Draught, maximum, aft	7′ 0″

Here as usual, the crew and chain locker are forward. The engines, which are of the hot bulb Semi-Diesel type of oil engine, are amidships, over which is a small bridge. The Pilots and Officers are quartered aft, and the after peak is utilised as a store,

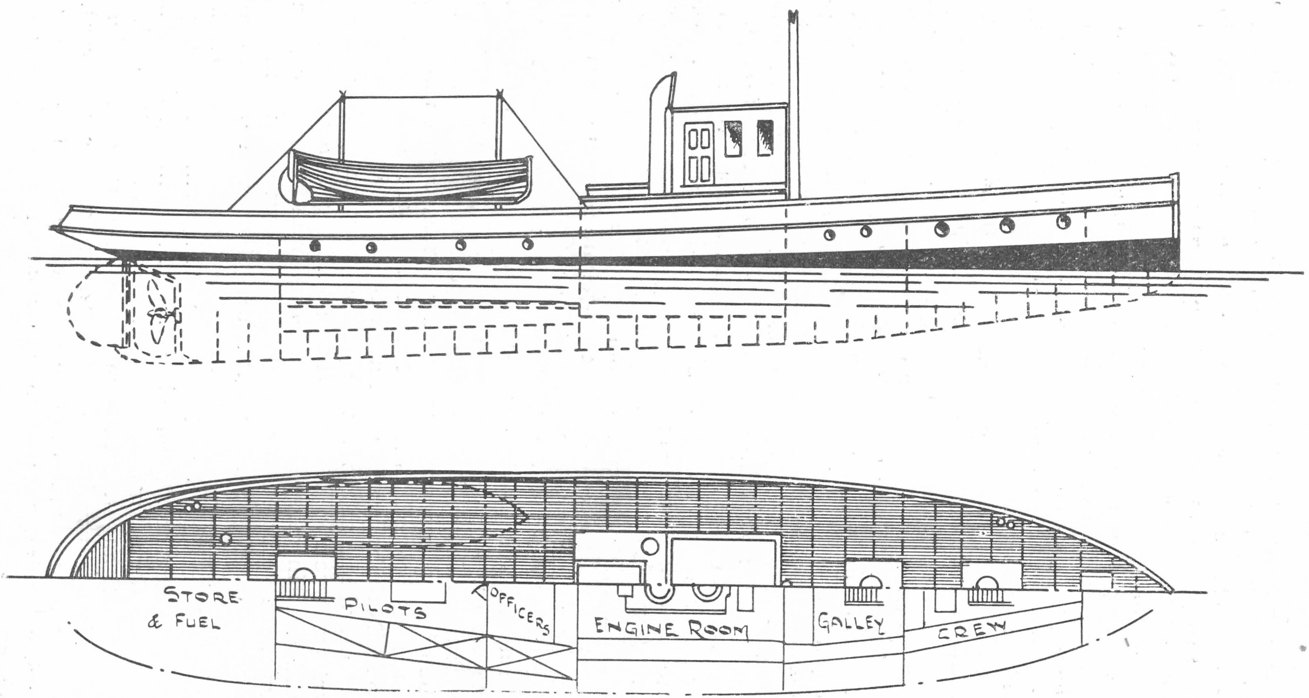

FIG. 139. GENERAL ARRANGEMENT MOTOR PILOT BOAT.

the oil and fresh water tanks being at the side against the frames. This could be open to criticism. The deck, it will be noticed, is kept as clear as possible. Except for the necessary companions and fittings, the former being of the steel screw-down type, the decks are clear, and capable of enduring seas to wash over them. Two motor launches are, however, carried, one on each side, under davits, special stands of angle iron being fitted at the side to allow them being easily launched. No funnel is fitted, the exhaust gases being emitted at the water line, and a short pole mast for carrying signals, etc., is fitted immediately abaft the bridge house.

Although there may be no special demands as far as the construction goes, these vessels require to be substantial. Continuity of strength, both longitudinally and transversely, is easily obtained, since there are no serious breaks, so it is usual to follow the established rules for straightforward construction, due allowance being made, owing to the conditions of service, in the scantlings to ensure general and local strength and rigidity. Additions of between 5 and 10 per cent. are allowed over and above that required normally, according to the conditions the certain vessel may have to encounter. In small boats the keel is of the single bar type, extending, if possible, all fore and aft, in one piece. In larger boats, however, where a vertical keelson plate is fitted in the centre, it is usual to fit the side bar keel, so that the keelson plate may be riveted to the keels. The keelson plate can be fitted with the single bar, of course, but cannot be fastened thereto. Owing to the shape of the under water body it is impracticable to fit the flat plate keel.

The longitudinal strength is given by one or more keelsons of double angles, fitted back to back, or in the case of large boats, double angles and the vertical plate. Bilge keelsons are adopted if the radius of bilge is large, and side stringers one or more in number, are continued as far forward and aft as practicable. Where only one stringer is fitted, either single or double angles are used, and it is the more advisable plan, especially if the boat be approaching near the size required for two side stringers, to fit, instead of the one stringer made of two angles, two stringers of single angles spaced equally distant between the bilge keelson (if fitted), or the tops of the floors at the top of bilge, to the underside of deck. By this the strength afforded by the stringers is distributed over a larger area. The breadth of the vessel never warrants the fitting of any longitudinals under the deck, although a single angle is often placed longitudinally under the beams, and attached to them by angle lugs, so as to form a runner angle for the pillar heads and thus distribute their support more equally. The deck stringer plate, which is an important member of the longitudinal system of framing, should be of a substantial thickness, and not reduced in thickness to any material degree at the ends of the vessel.

The floors are usually deep owing to the shape of the hull, and are always continued well round the bilge. Sometimes the upper edge is flanged to give some stiffening in addition to that given by the reverse frames, and this method is very commendable, since besides giving that stiffening, it allows better fastening with the keelson angles. It need only be employed with the larger vessels, however, the single reverse frame affording quite sufficient stiffening for the small floors. There is nothing unusual with the transverse system of framing. It is, however, advisable to give the deck as much support as possible, and also to reduce any tendency to racking stresses, since in a sea-way large quantities of water will fall on the deck, and the severe rolling will very soon make known any weaknesses in these directions. The beams, therefore, are often fitted at every frame, this being easily possible since the only breaks are the usual engine and boiler rooms. Forward and aft of these spaces the beams can be upon every second frame, the ends of the half beams in way of hatches and companions, etc., being tied together by a carling composed of the same material as the beams. In the engine room it is often possible to fit perhaps one or two full beams, and whenever such is possible full advantage should be taken. Half-beams can, however, always be utilised in way of the engine and boiler spaces, and if the ends are well tied together, either by fitting a carling angle, or continuing a plate down below the beams and attaching their ends thereto by angle lugs, sufficient compensation can be given without rendering any local weaknesses. Sometimes a heavy strong beam is placed at each end of these two spaces, and these materially assist in the provision of compensation, but they need only be of the same section as the ordinary beams, built-up and semi-box beams being absolutely unnecessary with boats of so small a breadth and spaces of so small a length.

The bottom plating while being of slightly thicker material than would be used with normal vessels, is not reduced to any appreciable extent towards the ends of the boat, for the reason that sufficient allowance must be made for possible panting stresses, which may be very acute in bad weather.

The side plating is of the same thickness as the bottom plating, but the sheer strake and the bilge strakes are increased suitably for the respective parts which they have to play. It is not uncommon for the sheer strake, which affords considerable longitudinal strength, to be of the same scantling as the garboards. In order to offer some protection to the side plating one or two heavy fenders are continued round the sides of the vessel, generally at the top and bottom edge of the sheer strake. They are often of American elm, attached to the plating by double angles, into which they are fitted, and faced with half-round or convex iron to avoid excessive wear and tear. Sometimes half-round or convex iron bars are secured to the exposed areas of the bows and forefoot,

but this would only be necessary with large vessels on special services.

In order to reduce rolling, when at sea, bilge keels are often fitted at the turn of bilge. These are usually composed of double or single angles, according to the type and size of the vessel, and a bulb plate. The depth of the plate should only be just sufficient to warrant their effectiveness, and care should be taken to ensure that they are not unduly liable to damage, since should they be torn away, the accident may be attended by very dangerous results. The bilge keels are placed at that point furthest removed from the centre of oscillation, and continued to a reasonable distance forward and aft of amidships, normally to the surface of the plating.

For the protection of the decks from large masses of water, and to afford a protection for the crew, bulwarks are fitted to all pilot boats. The height of these depend more or less upon the length of the boat, but they should never be less than 2 ft. 6 ins. from the deck at side to the top side of the rail. They usually fall in a little, gradually coming nearer the vertical as they proceed forward and aft, so that they fall outwards at the stern and become vertical at the stem. The plating, which should be of substantial thickness, is supported at intervals by stanchions, composed of specially forged iron rods with palms for attaching them to the bulwark and deck plating, or by angle iron bars suitably smithed to allow for attachment. Large freeing ports are necessary, at the rate of at least one square foot of freeing port to every 70 square foot of deck area. These may be made in one or two doors, according to the height of the bulwarks, and always open outwards to prevent them swinging inwards and thus becoming jambed. When the bulwarks fall outwards towards the after end, these doors cannot be fitted, and it is often necessary to allow rather larger water ports; the water on the after deck will always run amidships, owing to the sheer, and will find its way out through the water and freeing ports there.

The deck fittings do not require very much consideration. A powered or hand windlass stands upon the forward deck. If the anchors are of small weight a hand windlass is all that is required, but since all anchoring gear is on the large side, with vessels over 60 ft. in length, it may be found necessary to fit some kind of powered windlass. With steam the cylinders are, as usual, coupled directly upon the driving shaft, but in the case of motor windlasses it is not uncommon to instal the engine in the fore peak, and by an arrangement of bevel gears and shafting led through the deck, are geared upon the driving shaft of the windlass. The loss of power in this arrangement is considerable when compared with the direct coupling, but the great protection afforded to the engine when situated below the deck, especially when it is considered that the engine, if placed on the forecastle deck, is in one of the most

exposed parts of a ship, fully warrants the loss in power, which upon the point of deterioration, is fully compensated.

Bollards, fairleads, etc., are fitted as normally, where desired. The hatches and companions to the spaces below the deck should in all cases, when closed, be watertight. For this reason steel hatches which are secured by thumb screws, generally similar to those employed in the Royal Navy, are fitted. This point is not always pressed, however, and the common semi-circular wooden hatchways and companions are adopted. The coamings should always be of sufficient height to prevent water which may be washing over the decks, from running down to the cabins. This point should always be brought to mind with the deck houses, for much annoyance can be caused by neglecting this small matter.

The steering engine, which is needed with almost all the pilot boats, should be of the quick acting type, suitably protected by a casing. The leads aft, of chain cable, are shackled to buffers to relieve any shocks, etc., and the semi-circular quadrant, built up of two or three forged arms, with plates and angles, still seems to be preferred as the stern-gear. It is essential that some form of auxiliary steering should be supplied for the event of the steering gear becoming broken. This is usually in the form of a spare tiller, the foot of which is suitably shaped to ship over the rudder post head, some suitable locking pin being supplied.

It was mentioned at the beginning of this chapter that besides stability, speed was important. That the latter requires special consideration will be easily seen from the fact that it may often be necessary to catch up large, deep-water vessels to pick up or drop a pilot, and it is most undesirable that these large vessels should have to wait any considerable time. If there be several boats picking up or dropping pilots, there is much work to be done by the pilot boat, and a good turn of speed is a valuable asset.

The means of power has since the first steam pilot vessel until recent years been the vertical steam engine, but lately the claims of the internal combustion engine has been put forward very forcibly. That the latter engine should not be preferred owing to its unreliability is now of no value as far as arguments go, since the engines of the heavier type have already, by actual service, proved the fallacy of such arguments. Messrs. Perman & Co. have installed several of their Kromhout engines in foreign pilot boats, which have by all reports more than fulfilled what was expected of them, yet as far as Britain is concerned there seems a decided slowness with this type of engine. Curves of the speed and power suitable for pilot vessels are given in Fig. 140. The speeds are between 8 and 12 knots, and the I.H.P. required is given. If B.H.P. is required (with the Semi-Diesel engine) an allowance of 8 to 12 per cent. must be given.

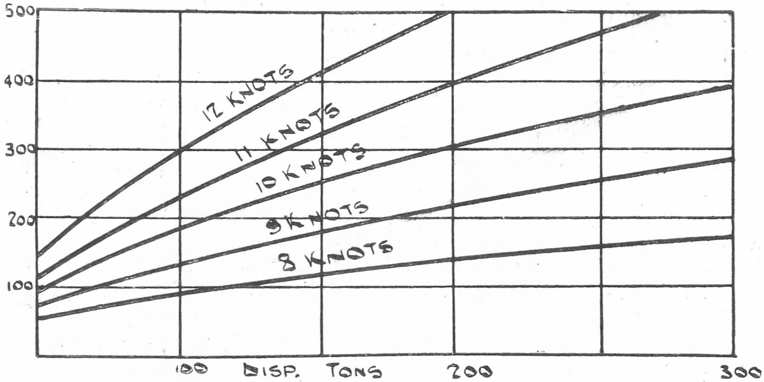

FIG. 140. SPEED AND POWER CURVES PILOT BOATS.

Pilot boats are high powered, the speed length ratio varying between 1.00 and 2.00, although at cruising speeds a ratio of about 0.8 is more usual. This means, therefore, that while the engines may be running at half-load for some considerable time, they may be required, at a moment's notice, to put on an over-load for some short period until the particular business is discharged. The resistances which increase considerably in proportion to the speed means that while at low speeds an engine may only be required to develop, say, 50 H.P., at full speed over 150 H.P. may be required. An ingenious method to overcome this was instituted by a Dutch Pilotage Service. Twin sets of Semi-Diesel engines were installed, so that when cruising, only one engine of 60 B.H.P. was running. When required to develop full power, the other engine, by an electrical starter, was set going immediately, thus with two engines "full out" a total of 180 B.H.P. was being developed. This in many respects is a novel and effective method of getting over the difficulty, and has the advantage that normally one engine may be undergoing minor repairs without the vessel being totally disabled, and the chances of total breakdown at sea are reduced to half. The initial cost, we might add, was less than that of a single steam set with boiler.

There is apparently some great tendency for four-bladed propellers being fitted to pilot vessels, for over a large number of cases extending over several years, 85 per cent. of the propellers fitted have been four-bladed. That this type of propeller holds several advantages is well known, and the more even balance makes a continued voyage on small vessels, where every shock is keenly felt, rather more comfortable. The evenness of running, however, has, as far as the Owners are concerned, further results, since the even running of the engines will tend to their longer

life. However, it is important that a propeller, which, as with the pilot vessel, is to perform a double duty, or rather to be equally satisfactory under two different conditions, shall be such that it fulfils its dual rôle with effectiveness and efficiency. This brings two main problems, *i.e.*, the determination of the most satisfactory pitch and diameter. The slip per cent. varies considerably with various classes of pilot boats, and with the type of engine and its revs. per minute. A high speed engine will often give a greater slip per cent. when running slow than at high speeds, especially with a fast boat. With a slow speed engine the slip per cent. will remain pretty constant, except when very high speeds are reached. Taking an example, supposing a vessel is required to run at 8 knots when the engine is making 80 R.P.M. it will only make 12 knots when running at 160 R.P.M., the proportion of pitches, if the same slip per cent. be kept, will be 1.8 : .35. It is, therefore, advisable to obtain the greatest effective pitch, taken on a curve, of speeds between the lowest and highest to which it is intended to run the vessel. Having obtained a suitable pitch, the diameter can be kept within some reasonable limit, and it is unwise to exceed 1.25 or go below 0.8, as a pitch diameter ratio, with steam vessels. With propellers driven by oil engines the limits must be suitably reduced.

If the area of the blades be increased the power of the propeller can always be effectively developed without any increase in diameter, and this is important. If a large diameter be persisted with, the pitch angle will become most inefficient, and when a good turn of speed is required the results will be far from satisfactory. If four blades are fitted to the propeller the area can be easily absorbed, while the diameter can be normal, thus we find further advantages of the four bladed propeller, and it may be noted that with all fast craft, whether it be a launch or destroyer, the pitch and diameter ratios are not sacrificed, but kept within suitable limits, and the blade area regulated to absorb all the given power effectively. The ratio of the developed area to that of the disc area is primarily dependent upon the pitch diameter ratio, for we have previously seen that by reducing the diameter we are at liberty to increase the surface area. If the rudimentary ratios are normal, the disc area ratio may be between 0.30 and 0.42, the latter figure being for four bladed propellers of small diameter. The latter figure should not be exceeded to any great extent, else certain troubles will be experienced, through insufficient clearance, etc., which will entirely destroy the efficiency of the propeller. If this is followed a projected area ratio of 0.8 or thereabouts will be easily obtained, and since that figure is normally good, it is inadvisable to exceed it to any appreciable extent.

Chapter 14.

FIREBOATS.

The Fireboat is a recently developed craft, and although comparatively only a few have been built within late years, considerable progress has been made in the powering and the design. It is evident that a boat of this class, while spending most of its time moored alongside a pier or wharf, must, nevertheless, be prepared to proceed to a scene of fire within a moment's notice. This means, therefore, that the boilers with the steam set must always be kept up to working pressure, thus the stand-by losses greatly exceed the actual working costs. To eliminate the high stand-by losses, various plans and schemes have been suggested. Some Fireboats took the form of a tug, with pumping machinery installed. While to some extent this plan seems quite good, it is obvious that should a fire call be received when the tug was engaged towing some miles away, the time taken in dropping the tow and getting to the scene of the fire would be sufficient for the fire to be out by the time the Fireboat arrived. In 1884 a French engineer proposed a plan whereby stand-by losses, and loss of time were to a great extent eliminated. The scheme was tested with apparently good results, for in 1887 the scheme was carried out in practice, two South French towns having the sets supplied. Several light flat bottomed barges were constructed, and pumping machinery, hoses, monitors and small vertical boilers, etc., were fitted complete. A fleet of tugs were partially requisitioned, so that when a fire call was received, the tug which happened to be nearest the station towed the barges to the scene of fire. Some years later this plan was improved upon by fitting electric pumping gear instead of the steam, and although here the stand-by losses are reduced to a minimum, there was still considerable loss of time owing to the tug having to drop the tow, and pick up the barges. In England there were at this time several steam fireboats in commission, but many which were built were afterwards put out of service owing to the cost of upkeep.

When the internal combustion engine had proved its reliability for marine work, attention was soon turned to the installation of this type of engine in the Fireboat. With this engine the stand-by losses are negligible, and since no stokers are required, it may be said that here is the ideal engine for this type of vessel.

The conditions of service may be classed under four headings—

1. Capability of quick starting.
2. Speed.
3. Handiness when under way.
4. Capability of working in difficult places, *i.e.*, where there is small depth of water, etc.

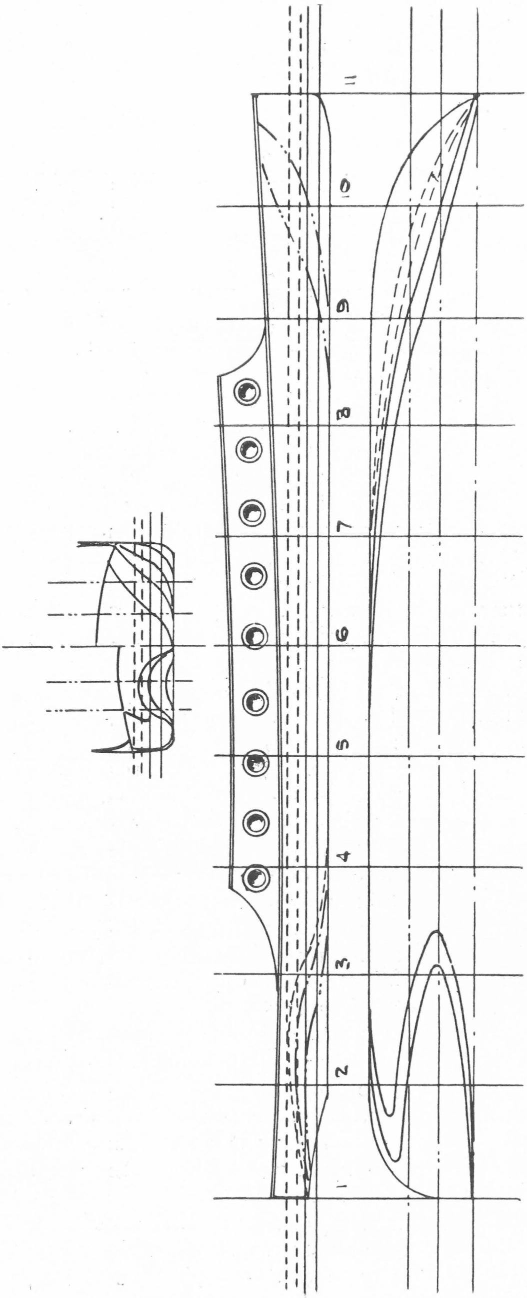

FIG. 141. SHEER DRAUGHT RIVER FIRE BOAT.

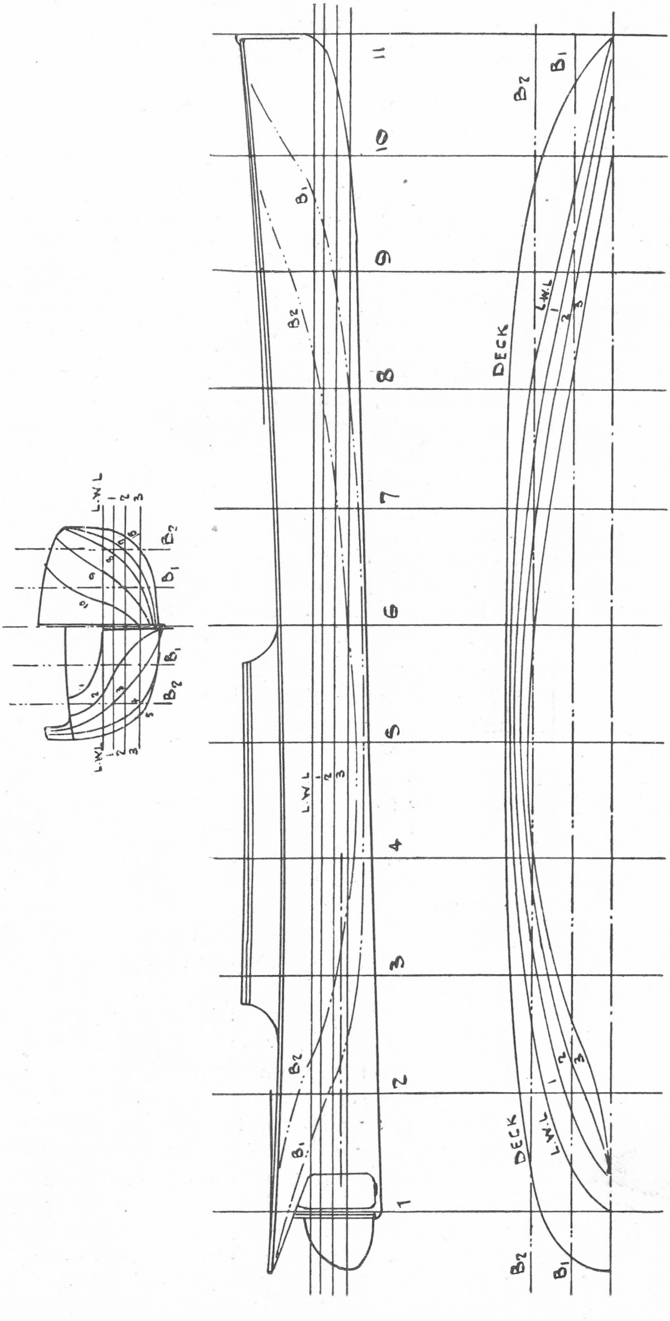

FIG. 142. SHEER DRAUGHT HARBOUR FIRE BOAT.

These requirements more or less develop the class, and produce a special type of hull. Breadth and depth are reduced to a minimum compatible with seaworthiness and efficiency. With boats working on a river station, the breadth should allow the boats to pass easily under the narrowest bridge within its working radius, and the draught should be such that the boat may get reasonably near the bank. With boats stationed at the mouths of rivers or in harbours, they must be of easy dimensions to allow them to work in all parts, and should be able, if the occasion arise, to proceed some distance out to sea. There is a considerable difference between harbour and river fireboats owing to their different service and restrictions. With the river craft, the lines of the hull are usually very full, the block coefficient sometimes being as high as 0.75. The large breadth-depth ratio produces a rectangular midship section, and in order to obtain sufficient displacement it is necessary to keep the section as full as possible. It is, however, advisable to give somewhat fine lines to the forward sections for the sake of speed. The small depth of the sections does not allow for much shape, but it will be seen in Fig. 141, that in the sheer draught of a river Fireboat, the forward lines take a V shape, gradually merging into the U shape as they progress aft. The after lines are necessarily full, and take the contour of the midship section aft, without any considerable alteration to the transom. In this vessel as with most of the modern river fireboats, the screws are working in two separate tunnels.

The harbour Fireboat takes a more easy shape, since there is not so much restriction on draught.

Fig. 142 gives the sheer draught of a harbour Fireboat which was built for service in the East. The midship section, it will be noticed, is somewhat of tug form. There is a considerable rise of floor, and a good, round, easy curve of bilge. The forward waterlines are comparatively fine, and with the sections there is a little flare introduced. The after waterlines show a good, clear run to the propeller, whilst the upper waterlines are somewhat full to provide ample buoyancy. The block coefficient is not high, being 0.503, and although the underwater body is comparatively fine, a very seaworthy hull shape is given.

A fairly substantial sheer is given to the larger craft, although this is unnecessary with the river boats.

Stability is an important consideration, especially with the harbour boats. With the river craft it is assured owing to the shape of the hull, although here it is not such a necessity as with the harbour craft. It is equally undesirable to have the boat too "stiff," as it is to have the boat too "easy," since the efficient working of the monitors, etc., in partially smooth water would be exceedingly difficult. With the heavy weights of machinery, etc., below, tending to bring the Vertical Centre of Gravity comparatively low, there is a tendency to give too great a Metacentric

height, and for all ordinary purposes it should not exceed 15 to 19 inches.

Another point which bears upon stability is the disposition of the weights on board. With a vessel of small size, it is desirable, wherever possible, to provide some reasonable balance of weights in order to equally dispose of the stresses in the structure, and to assist in the longitudinal stability of the boat. With the fire boat, the weight of the engines, pumping machinery, and boilers, when these are fitted, are more or less concentrated over a small area of the ship's bottom. It is obvious, therefore, that the disposition of the various stores, should be such that the shearing forces which would otherwise present themselves, are reduced to the minimum, and the necessary longitudinal balance preserved.

Fig. 143 gives the General Arrangement of the "Delta II.," a fireboat which was built in 1913 from the design of Messrs. Kemp and Wells, to the order of the London County Council for service on the Thames. Her dimensions are :—

Length, overall	... ...	100′ 0″
Breadth, extreme	... ...	21′ 6″
Depth, moulded	... ...	4′ 1″
Draught, loaded	... ...	2′ 0″

A chain locker is situated well forward, abaft of which is a hose room and store fitted up with batten racks, etc. The engine room is situated amidships, and the main power installation consists of three sets of Kromhout engines, each developing 56 B.H.P., which gives the vessel a speed of 10½ knots. For starting and reversing 10 steel air bottles are fitted together with a small air compressing plant. The engines may be worked on compressed air alone, the compressing plant being able to revolve the main engines at a slow speed, thus the most certain method of starting has been adopted. The main pumps are driven direct from the main engines, and are of the Hatfield type, capable of discharging 1,450 gallons per minute, at a pressure of 120 lbs. per square inch. In addition to the main machinery, there are fitted two separate electric-lighting dynamos, bilge pumps, etc.

The crew are quartered abaft the engine room, following which are the gallery, pantry, and w.c. In order to provide sufficient head room, it has been necessary to build up the sides of the vessel. The deck arrangement is quite simple. A windlass is fitted forward, and the necessary hatches are fitted for access to the store below. A small bridge is situated over the hose room, and six monitors are fitted to the fore and main deck combined. The jets have an effective radius of about 160 feet, and each can throw a stream of water to the height of 60 feet.

A searchlight is fitted to the after end of the main deck, while for working purposes the short after deck is kept clear. It is of interest to note that three propellers, each working in a separate

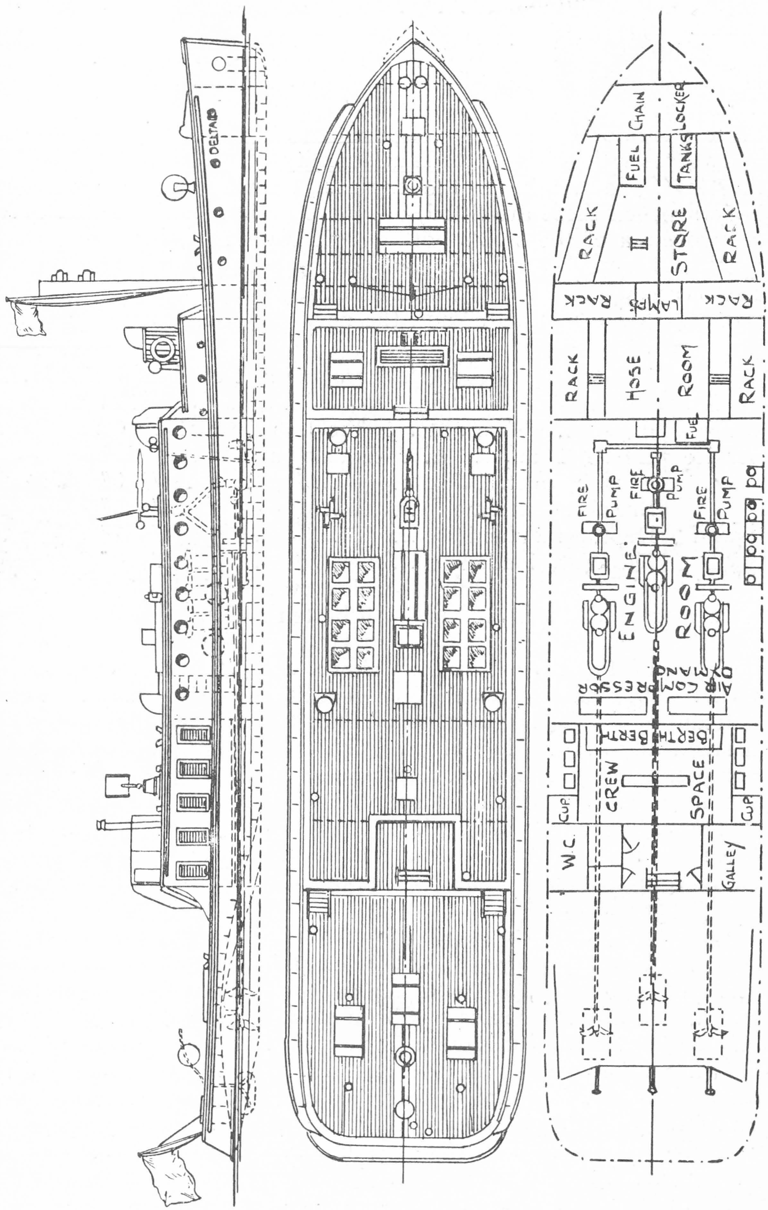

FIG. 143. GENERAL ARRANGEMENT "DELTA II."

tunnel, are fitted. The propellers are 3 ft. in diameter, and have been fitted as high as is compatible with efficiency, that is, slightly more than half the propeller diameter is below the waterline. Three single-plated balanced rudders are fitted, one in each tunnel, care being taken to fit them sufficiently high so that they should not sustain damage should the vessel at any time take the ground. Inspection hatches are fitted to the after deck over the propellers for accessibility to them.

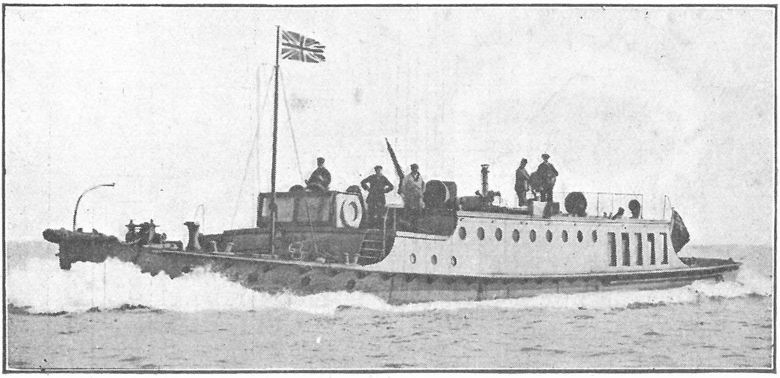

FIG. 143A. "DELTA II."

Fig. 144 shows the General Arrangement of a Fireboat of the harbour type. This vessel measures 90 ft. in length between perpendiculars, and has a moulded breadth of 16 ft. 6 ins. and a moulded depth of 7 ft. 3 ins., while loaded she draws 5 ft. 3 ins. of water aft. A chain locker is fitted in the forward peak, and the crew are quartered in the forecastle. A hose room complete with racks, etc., is fitted up abaft the crew's space. A single boiler of the Scotch type is situated forward of amidships, and side bunkers are provided. It is more usual, however, to fit, for purposes of cleaning, and for economy, two vertical boilers, so that when necessary one of the fires may be let down without the boat being out of service for the time being. The engine room occupies a large amount of space. The main propelling machinery consists of a triple-expansion engine, developing 180 I.H.P., and giving the boat a speed of 9 to 10 knots. The main pumping plant consists of a high speed vertical engine of the multi-velocity type, directly coupled to a centrifugal pump, of the one-stage type. Two donkey pumps, directly coupled with two centrifugal pumps, can be brought to serve the monitors. The total working pressure is 268 lbs. per square inch at the pump delivery, which giving a pressure of 100 lbs. per square inch at the jets, can throw a stream of water over 100 ft. in height, and can give an effective range of 180 ft. Thus 1,450 galls. of water can be dealt with in

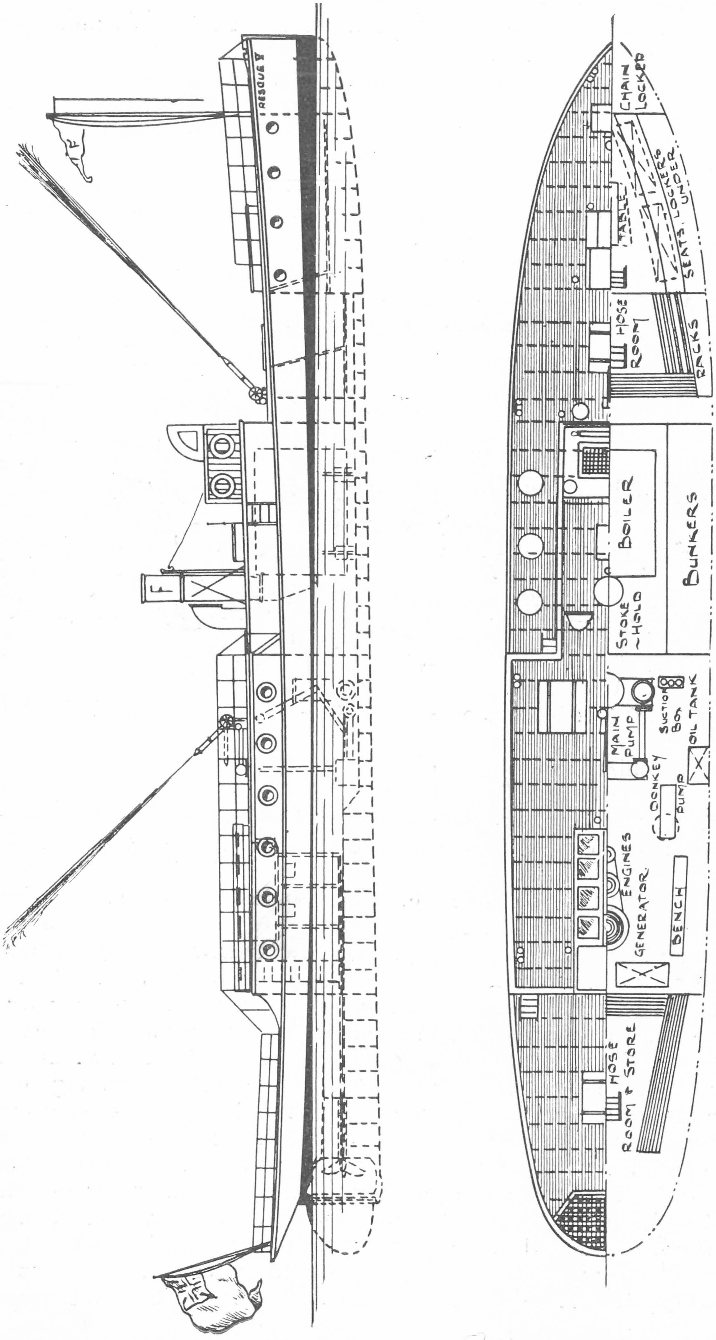

FIG. 144. GENERAL ARRANGEMENT "RESCUE V."

one minute. Other usual engine room donkey machinery, of course, is supplied.

A further hose room and store fitted at the after end of the vessel completes the arrangement.

Fig. 145 gives curves of approximate dimensions, weights, displacements, etc., for Fireboats. These curves are based upon the harbour type of boat, and in designing a boat for river service, it will be necessary to acquaint oneself with the local conditions in which the boat will work, in order to make the necessary restrictions on draught, breadth, etc.

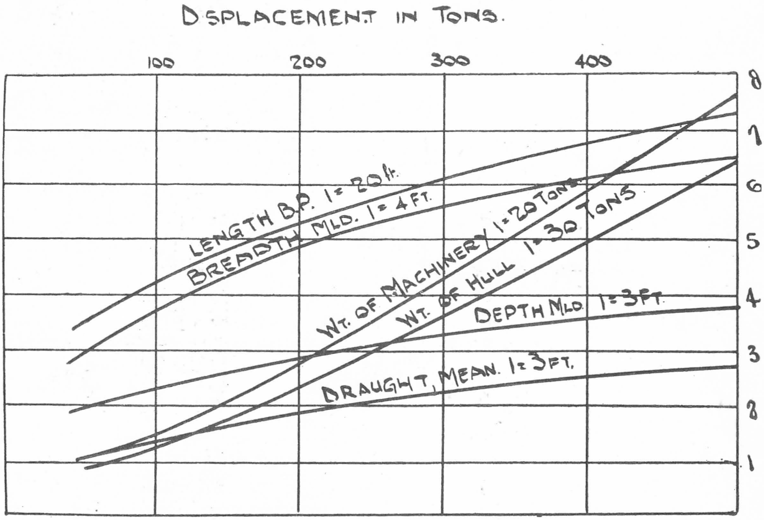

FIG. 145. CURVES OF DIMENSIONS, ETC., FIRE BOATS.

Steel only is used for the construction of these boats, and one of the chief considerations is the provision of ample strength of bottom, owing to the excessive strains experienced when the machinery is working. It is necessary to build up the floors as high as practicable, and to provide very substantial bottom plating. In the harbour boat it is usual to fit the bar, or side bar keel, but in the flat-bottomed river craft, it is more economical and simpler to fit the usual flat-plate keel. The engine seating should wherever possible be extended as far forward and aft as practicable in the form of intercostal keelson plates, and the top angles continued on the tops of the floors as far as possible. It is inadvisable to introduce any break whatsoever in the longitudinal framing, as it is upon this that the rigidity of the vessel mainly depends. The side plating should be of substantial thickness, and it is common practice to double the sheer strake so that no danger of damage may arise out of the boat coming

alongside a wharf or alongside another vessel in a rough manner, since at a time of fire, much judgment is not always given when greater necessities are at issue. In the "Delta II.," Fig. 146, it will be noticed, a deep fender, composed of a flat plate and angle, faced with half-round iron, and supported by plate brackets attached to the hull by angle-bars, is fitted. This fender also provides a walk forward and aft.

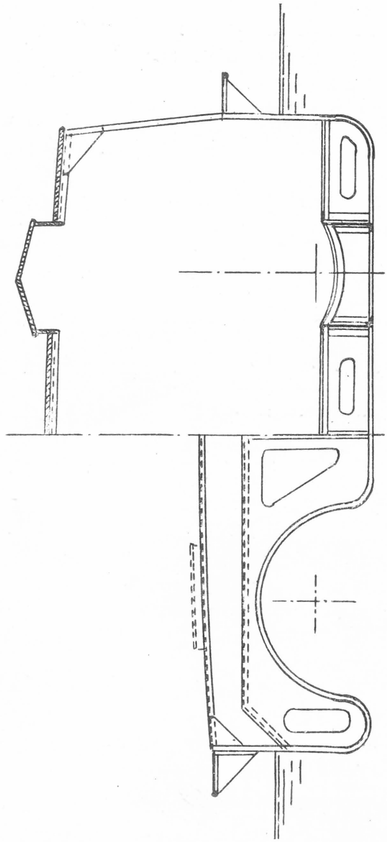

FIG. 146. MIDSHIP SECTION AND AFTER SECTION TUNNEL SCREW FIRE BOAT.

As a rule there is little difficulty in arranging the beaming, although it is necessary to provide sufficient strength of deck. Except where steel decks are fitted, when the beams may sometimes be spaced on alternate frames, it is usual to fit the beams at every frame. Difficulty is sometimes experienced in arranging the beams in way of the engine space, but here, if hatches be fitted

over the main pumps, and these be well fitted so as to preserve continuity of structure, beaming may be otherwise continued as normally. A box-beam is sometimes fitted at each end of the boiler space and at the after end of the engine room, but this provision is hardly necessary in these small boats, the extra

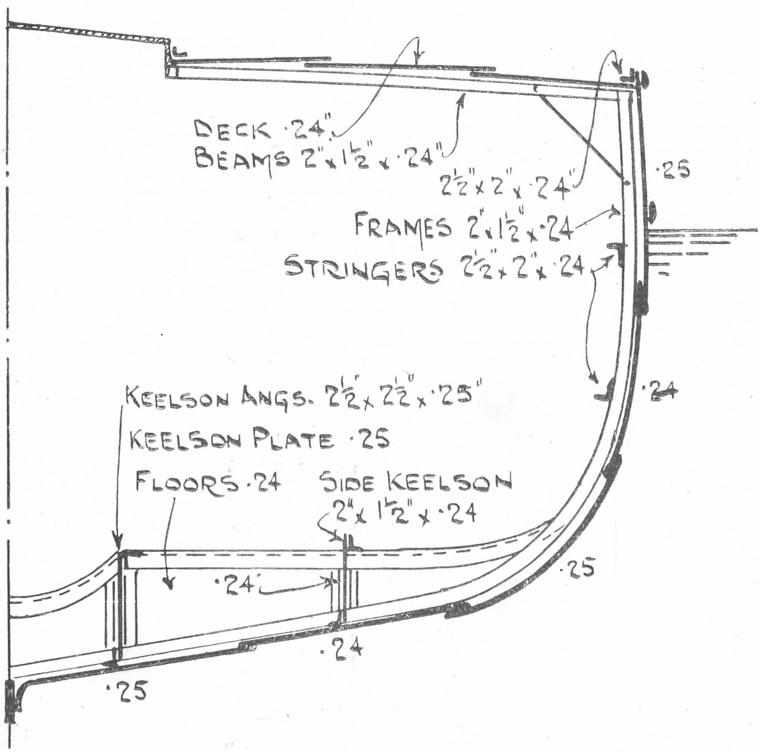

FIG. 147. MIDSHIP SECTION, HARBOUR FIRE BOAT.

bulb-angle being sufficient compensation. Where it seems necessary because of the height of the machinery, to build up an engine casing, it is better to carry the sides of the vessel sufficiently high to cover the machinery space and to build the deck complete from port to starboard. The advantage of this will be seen, that, while giving a clearer and better deck for working, etc., the continuity of the beams, and the greater depth of side, gives a far stronger, more efficient, and cheaper hull.

If the depth of the side of the boat be not very great stringers are not fitted, although it is advisable to give some panting stiffening forward, but this need not be more than a single angle fitted

on the face of the reverse frames, and continued for about one quarter of the length of the boat aft from the stem.

Where the length of the engine and boiler rooms are excessive, it is usual to fit a bulkhead between these compartments, and although this separation may be an inconvenience, it becomes necessary, for the provision of sufficient transverse strength.

Fig. 147 shows the midship section of the "Rescue V.," and the various details of construction will be easily seen.

The equipment of the fireboat is important, and although it may be more a matter for the Engineer, it will be dealt with, briefly, here. For an efficient flow of water to the monitors, it is necessary to have the higher speed pump, which preferably should be of the one or two-stage centrifugal type, and coupled directly to the engine, which in former times was invariably of the vertical steam type; such have now been displaced by the oil engine. Electric motors driven from accumulators have been tried, but the various losses, etc., fully warrant the fitting of more economical types of power. In the case of steam propelling machinery the pump engine was almost invariably driven by a separate engine, but with motors the water pumps may be fitted at the forward end of the main engines, and therefore, the greatest efficiency is obtained while pumping, and the initial cost is considerably reduced.

The speed at which to run centrifugal pumps is open to much controversy, but for speeds of 600 to 1,000 R.P.M., a power of about 100 to 300 B.H.P. should give good results.

A formula for giving the power required for certain capacities and lifts is given by :—

$$E.H.P = G \times H \times 0.00076.$$

Where E.H.P. = Effective Horse Power.
G = Gallons per minute.
H = Height of lift, in feet

The size of pump may be found by :—

$$D = \frac{(8.80 \sqrt{H} + K) \times 230}{R}$$

Where,

D = Diameter of fan, in inches.
K = Constant, varying between 5 and 10, but usually taken as 6-7.
R = Revolutions per minute of fan.
H = Height of lift, in feet.

The nominal horse power required for pumps, etc., depends upon the diameter of the fan, and the quantity of water it is required to deal with,

Consider a 8 ins. diameter of fan, required to deal with 1,000 gallons per minute, it will be found that the nominal horse power required will be about 0.303 N.H.P. per foot of vertical height. This figure increases to 0.700 N.H.P. for a 12 ins. pump, with a capacity of 2,300 galls. per minute. Allowing for slip, etc., a 8 ins. pump should run at about 736 R.P.M. for a lift of 25 feet, and a 12 ins. pump at 604 R.P.M. for the same lift. Of course, the larger the pump the slower will be the revs. required for a given lift, thus a 24 ins. pump,absorbing 2.848 N.H.P. per foot of lift, and dealing with 9,400 galls per minute, will only be required to run at 300 R.P.M. The mechanical efficiency of pumps are generally between 80 and 90 per cent.

The size and shape of the monitor nozzles are important in the projection of an efficient stream of water, and the following gives a table of size, etc., for nozzles between $\frac{3}{4}$ and $1\frac{1}{4}$ ins. diam.

TABLE FOR PRESSURES.

Sizes and Distances, etc., for Nozzles.

Size of Nozzle.	Pressure at Nozzle. Lb./sq. in.	Pressure at Pump. Lb./sq. in.	Gallons per min.	Distance Thrown Vertical in feet.	Distance Thrown Horizontal in feet.
$\frac{3}{4}$ inches ...	40	46.5	85	60	45
	50	57.0	95	66	50
	60	67.8	105	72	55
	70	79.3	115	75	59
	80	90.5	125	80	62
	90	102.0	130	81.5	64
	100	114.3	135	83	67
1 inch ...	40	57.5	155	65	55
	50	71.5	170	74	60
	60	86.7	190	79	66
	70	100.0	205	84	73
	80	115.0	220	88	77
	90	129.0	235	92	80
	100	143.0	245	95	83
$1\frac{1}{4}$ inches ...	40	84.0	250	67	63
	50	105.0	275	76	70
	60	126.0	300	85	75
	70	149.0	325	90	80
	80	170.0	350	94	85
	90	190.0	365	98	90
	100	215.0	390	100	94

The pressures given are for indicated pressures, and an addition must be made for effective pressure. Distances are given for effective fire streams.

A very important consideration as far as powering is concerned is speed. This will be readily understood, as it is of utmost importance for a firefloat to arrive at the scene of fire as soon as possible after the reception of the fire call, and whether working in a river, or in a harbour, the local rules as to speed, etc., are "rather more honoured in the breach than the observance." That speeds over 12 knots are frequently required, in small vessels, needs considerably higher powered engines than are usually fitted in normal vessels of equivalent dimensions. The length-speed ratio

$\frac{V}{\sqrt{L}}$, seldom falls below 1.0, and is more usually about 1.4 to

1.7. The speeds are, in reality, uneconomical, for the proportionately great resistances which are set up at these speeds require abnormally high-powered engines. Take for example two vessels of the same size and displacement, and with little difference in their wetted surface, in one a 50 B.H.P. engine gave 9 knots, and in the other a 350 B.H.P. engine gave about 13.8 knots. It will

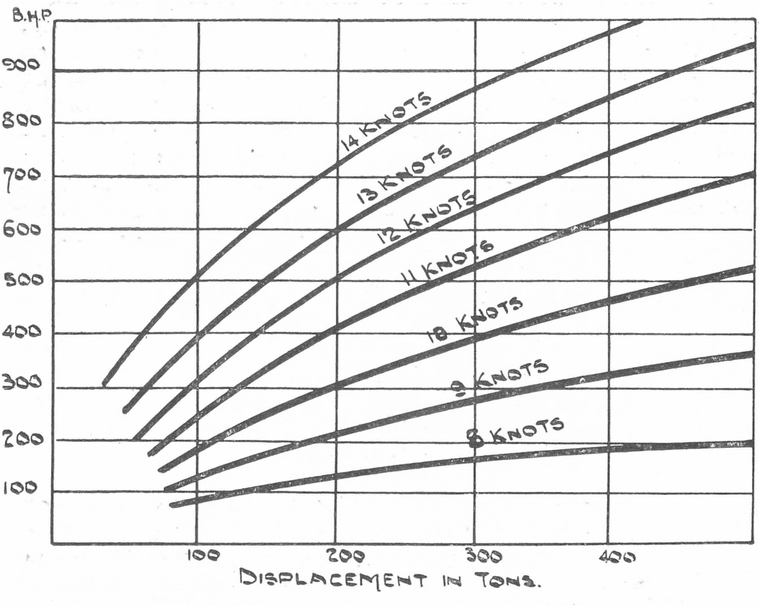

FIG. 148. SPEED AND POWER CURVES FIRE BOATS.

be seen that for 53 per cent. more speed, about 600 per cent. more power was required. This is seen in the Admiralty coefficient formula where the term of power is given as the cube of the speed.

The "Delta," which has been previously mentioned, has three engines, each developing 56 B.H.P., giving a speed of about 10 knots. The Admiralty coefficient is, therefore, about 117, and indeed, over a large number of firefloats, the coefficient is found to vary very little between 115 and 120. As the speed increases, however, there is a decided decrease in the value of the coefficient, and when the speed-length ratio is 1.8 and over, the Admiralty coefficient is as low as 95. Speed and power curves are given in Fig. 148.

The design of the propellers does not present many difficulties, especially when motors are fitted, since when high speed engines are fitted into a high speed boat, the propellers can develop their best efficiency, and trouble due to cavitation, etc., which is apt to arise in slower vessels fitted with high speed engines is practically unknown.

The pitch-diameter ratio can be kept fairly high, at about 0.9 to 1.25, while the area of the blades can be kept within practical limits. In the case of the propellers fitted to steam engines, the diameter is kept somewhat small, because the engines are usually of the higher speed type, and the pitch, therefore, is kept within practically the same ratio as the propeller driven by the motor. Having the pitch and diameter in close relationship, the area of the developed blades (the total) can be kept between 30 and 36 per cent. of the disc area, and with a broad tip, and a narrow root, to prevent a collar of water being choked around the propeller, the results obtained should give comparatively high efficiency. With an effective surface area, and suitable diameter and pitch, a small column of water will be projected aft at a high velocity which is by far preferable than the projection of a large column of water at a relatively slower velocity.

Chapter 15.

DREDGERS.

No hard and fast rules can be laid down regarding the modern types of dredgers and dredging appliances, since the great variety of conditions of service, etc., usually calls for a practically unique craft. Roughly the various kinds of dredging appliances may be summarised as follows :—

Type I.—Digger Dredgers.
Type II.—Suction Dredgers.

These two main types may be further classified as follows :—

TYPE I.

A. The ladder, or elevator dredger, with a continuous band of buckets.

B. The dipper dredger, with one dipper, or bucket, at the lower end of an arm or lever.

C. The grab dredger, sometimes known as the grapple, with a hinged bucket, or grab, at the end of a chain.

TYPE II.

A. The suction dredger, *i.e.*, the sand pump dredger.

B. The suction cutter dredger.

Compound dredgers, *i.e.*, comprising of two or more of the above types of dredging appliances, are often built for special service, but it is intended to treat with vessels equipped with one type of dredging apparatus only, since various combinations can be easily arranged from any two types of apparatus. Each type, as enumerated above, can be, with its subdivision, either independent of any barges, for the discharge of debris, and have hopper compartments arranged in the one hull, or have only the dredging apparatus, and be dependent upon some craft being moored alongside for the reception of the dredged matter.

Ladder or elevator dredgers, often termed bucket dredgers, are suitable for almost all services to which dredgers may be put, with the exception of hard rock work. Their great serviceability and their high power, render them the most common type employed for the removal of the heavier kinds of material, and their moderate cost of upkeep, and cheapness of repairs, bring them into favour with the owners of dredging plants. Their principle of working is simple. A continuous band passing over two pulleys or pivots, at each end of the supporting arms or ladder, which can be inclined to any reasonable angle, carries a series of buckets. The buckets at the lower extremity scoop up the material, and are carried to the upper pivot and discharged into a suitable shoot at the turn, coming down towards the lower extremity again, upturned, so that at the lower pivot another bucketful of material will be scooped up. The ladder dredger may be of the single or double ladder type. If single, the ladder is arranged longitudinally, and if double the two ladders extend out athwartships opposite one another, or are arranged longitudinally at each side of the vessel. For ordinary service, the single ladder holds many advantages over the double ladder. The smaller breadth of the former allows a better ship-shaped hull, and is more sea-worthy. The latter advantage is of importance in hopper dredgers, which may go to sea to discharge their cargo. Other advantages are that the single ladder dredgers have fewer working parts, are less open to damage, and greater efficiency is obtained with the same powered engines, since there is less loss due to friction. With the double ladder dredgers there is an advantage in that it is easier to dredge when near, say, a wall, and also that if one

ladder breaks down the vessel will not necessarily be out of service.

The capacity of the buckets depends upon the intended service of the vessel, and varies between 4 to 50 cubic feet. A convenient capacity for general service is about 30 cubic feet, with a speed of about 15 to 25 feet per minute. The average depth of water is between 30 and 50 feet, and it is not uncommon to average the working capacity to about 400 to 600 tons of stiff clay per hour. With very powerful dredgers this figure is often doubled when excavating soft sand, etc., and with heavy marl and chalk these larger dredgers can often deal with over 500 tons per hour. As previously mentioned, the bucket dredger cannot be expected to deal with very hard rock, but they are often employed in excavating the softer kinds of limestone and sandstone, and to facilitate this, spikes or tines are fitted to the upper rim-band of the buckets so that they may scrape away the soft, upper surface of the rock. Buckets will often pick up large boulders of rock and chalk, weighing anything between 1 and 3 tons apiece, but it is advisable to relieve them of any undue weight, and for this reason some substantial crane or derrick should be fitted at a suitable place near where the buckets emerge from the water, so that the heavy boulders may be lifted out.

Fig. 149 gives the general arrangement of a bucket dredger of the single ladder type. The machinery, it will be noticed, is situated aft, while the boiler is placed on deck alongside the ladder. A large steam winch, for controlling the ladder, is on the starboard side, while suitable accommodation for the crew and workmen is arranged in the deck house aft. The following particulars of the "Walter Glynn," a ladder dredger belonging to the Mersey Docks and Harbour Board, may be of use in estimating, etc. :—

Length, between perpendiculars ...	190′ 0″
Breadth, moulded	35′ 6″
Depth, moulded	13′ 0″
Draught, forward and aft	9′ 0″

Propelling machinery, two sets of triple expansion surface condensing engines, 14″, 22¼″, and 36″ by 24″, developing 1,200 I.H.P., which driving twin screws, give a speed of 10 knots.

Dredging machinery consists of a triple expansion engine, surface condensing, 12″, 18¼″, and 30″, by 24″ stroke, developing 300 I.H.P.

The capacity of the vessel is 400 tons of stiff clay per hour.

The dipper dredger is not used in England or on the Continent, but is frequently met with on the Great American Lakes, and at the mouths of the large rivers of the American continent. It works generally in a depth of water between 15 and 20 feet, and has one bucket (of between 1 and 12 cubic yards capacity) at the end of the lever. The bucket is operated in an upward curving sweep, similar to that of the steam navvy, as used for land purposes, and

the bucket speed is between 30 and 60 seconds per sweep, the former figure being for dredgers employed in sheltered waters and the latter for exposed waters. The dipper dredger is not so serviceable as the types of dredgers previously dealt with, the only point in their favour being that they may work and manœuvre in very

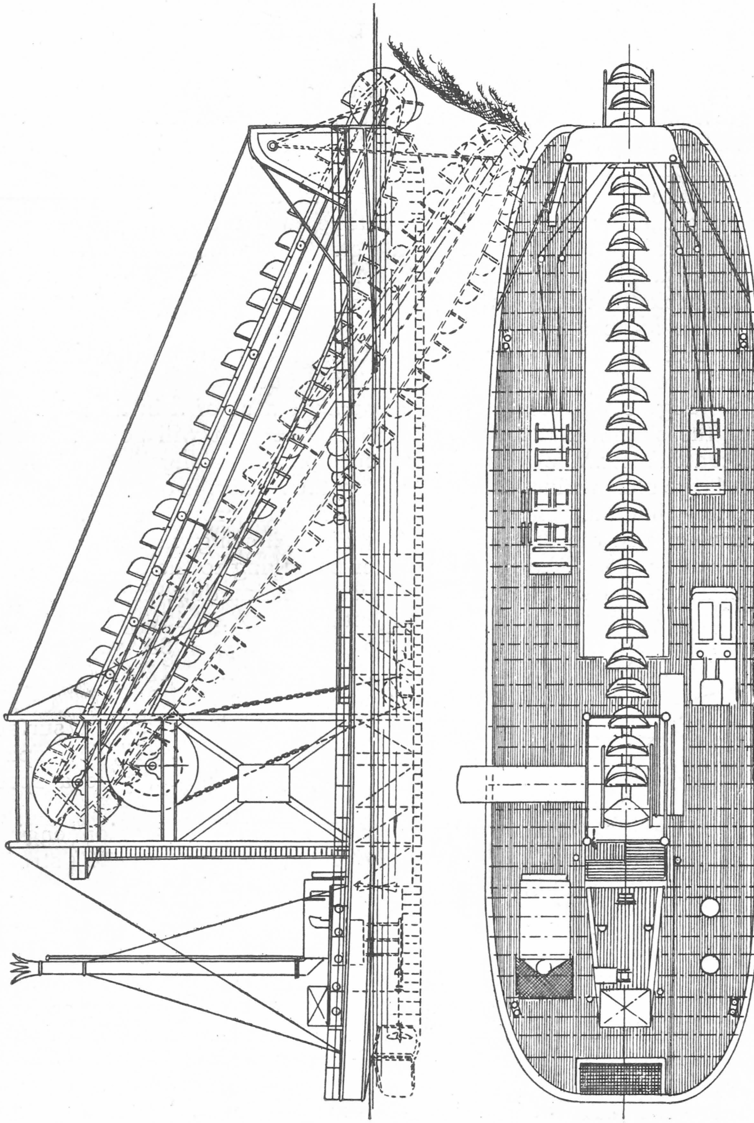

Fig. 149. General Arrangement Ladder Dredger.

restricted rivers. It is of interest to note that although employed in the earlier dredging of the St. Lawrence River, the most powerful of them were soon replaced by lower powered, but more efficient, ladder dredgers. The lifting capacity of the single buckets, however, exceeds that of the ladder dredger where large boulders are concerned, it being not uncommon for the single bucket to pick up a boulder weighing 10 tons and more with comparative ease.

The first kind of grab dredger was the primitive bag dredging appliance, which even now is often used when small scale dredging is required in ponds and small lakes, etc. This method employs a leather bag, of a capacity of about 12 to 27 cubic feet, which is attached, at its mouth, to a steel hoop, or collar. The hoop is attached to a stout spruce spar, between 15 and 30 feet in length, which keeps the bag at the bottom of the river, and allows it to be dragged along by a rope attached at one end to the spar and at the other to the barge. With about six men working about 2100 cubic feet of soft sand in this way may be dredged in eight hours, or with mud somewhat less.

The grab or grapple dredger, such as is used on the larger scale, consist of a large grapple, made in two parts, each of curved plates of suitable thickness, which, by suitable mechanism, controlled by the driver, can be open and shut at will. The grab can be either attached to the head of a jib-crane which allows the necessary raising and lowering, or attached to the end of a chain passing over a pulley or sheave at the crane head. With the jaws open, the grab is allowed to fall heavily under the influence of gravity, and bury itself in the river bed, etc., as the case may be. The jaws then being closed, the grab is raised withdrawing all that was caught between the teeth. Several methods for opening and closing the grab are fitted, and it is always preferable to fit double chains to the grab, since with the single chain the grab closes under its own weight, and cannot therefore be opened at will, and should a large rock be caught or any obstruction prevent the grab from being withdrawn, difficulty will ensue. With the double chains, the grab can be opened at will, in any position, and while requiring special chain leads, and therefore a special design of crane head, it is advisable, even should the first cost be greater, to ensure that no difficulties will arise in the working.

The most useful capacity for a grab lies between 60 and 120 cubic feet, and working at a depth of over 60 feet, can run at the rate of about one dip per minute. This would give about 200 cubic yards per hour, which, it will be noticed, compares favourably with the ladder dredger. The grab, unlike the bucket dredger, is unsuitable for extensive dredging operations, its chief use being in keeping clear small local areas such as the mouths of locks and dock gates. It is particularly useful in removing very soft mud and silt, which on being disturbed renders dredging by other

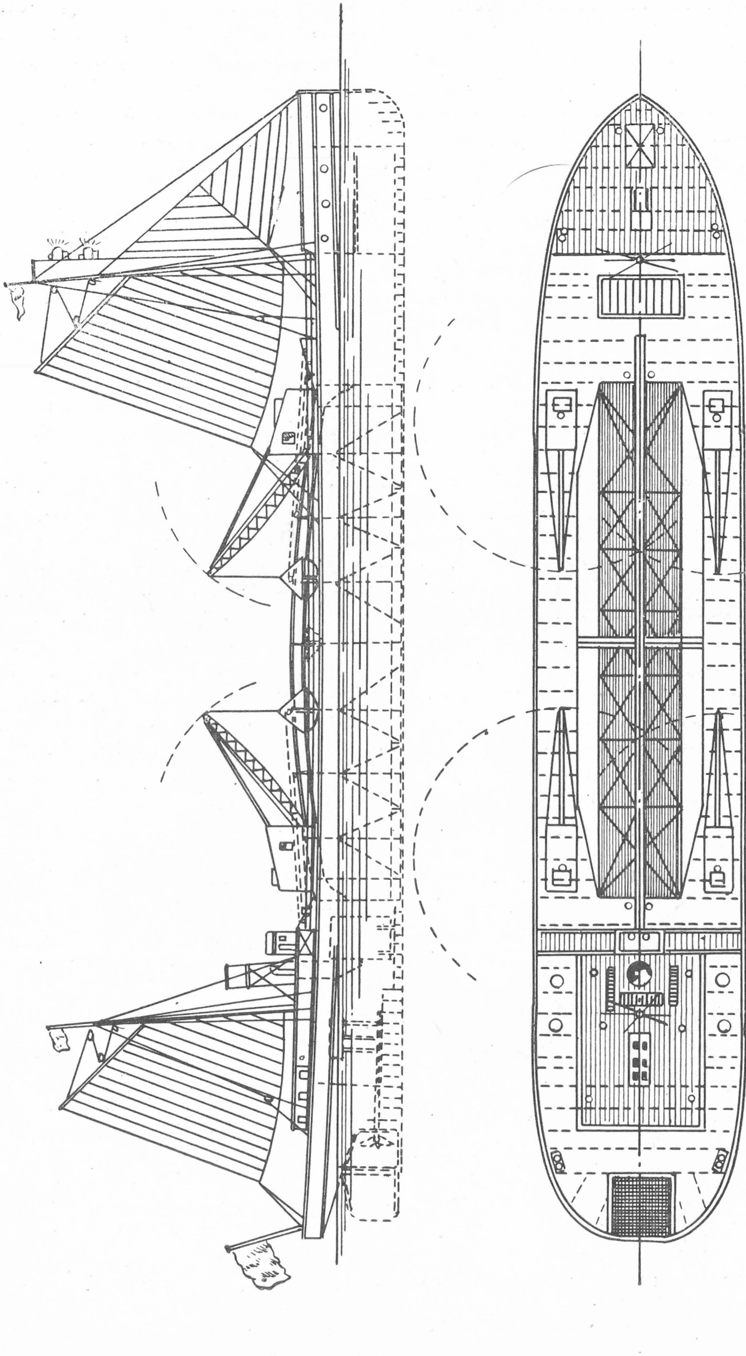

FIG. 150. GENERAL ARRANGEMENT GRAB DREDGER.

methods practically impossible. Further advantages are that the grab is capable of working in restricted places, and can pick up logs of wood, bales, etc., which are often dropped into docks, and tend to obstruct the fairways.

Fig. 150 gives the general arrangement of a 1,000 ton grab-hopper dredger, from which various particulars may be easily obtained. The principal dimensions are as follows :—

Length, between perpendiculars ...	200′ 0″
Breadth, moulded	34′ 0″
Depth, moulded	15′ 0″
Draught, maximum	12′ 0″
Grab Cranes, number	4
capacity, each ...	5 tons
radius, each	15 ft.
Grabs, capacity, each	75 cub. ft.

Suction dredgers consist essentially of a long pipe or tube, which can be lowered to a river bed, etc., and through which light substances, such as sand, can be drawn, and which can either be discharged into hoppers, or lead through pipes to some dumping ground ashore. The first experiments with this type of dredger were successful, and for certain classes of employment it is very unlikely that these will be superseded. The sand pump, so named because it was first employed in the dredging of sand, is generally of the centrifugal type, with one inlet. Two inlets are sometimes arranged, however, to reduce shock and concussion, but with efficient thrust bearings a suitable evenness of running should easily be arranged. The size and shape of the nozzle are important, since it is upon their efficiency that the ultimate efficiency of the plant depends. The efficiency of the suction is usually about 45 per cent., although 55 per cent. has been reached with some vessels. The comparatively low efficiency is due to the fact that a considerable quantity of water is inevitably drawn in with the sand. This is later pumped overboard again. Great trouble was experienced when the first pumps were fitted owing to the fact that the sand was also being discharged with the water. This has been overcome, however, by making the discharge pipe as long as practicable, and fitting suitable coamings, so that the sand may be trapped, and afterwards drawn off ; the slope of the pipe should not be too great since the slower the flow of the discharge water, the greater will be the quantity of sand entrapped.

Fig. 151 shows the general arrangement of a steam suction dredger, which discharges into her own hoppers. The advantage of this is that the water can also be discharged into the hold, and can be drawn off by a separate pump. The sand, owing to its weight, will sink to the bottom of the holds, the loss will then be eliminated, and the general efficiency of the craft increased. The arrangement of accommodation is simple. The Captain and Engineers are quartered aft, and the Crew forward immediately abaft the chain locker. The engines, both propelling and pumping,

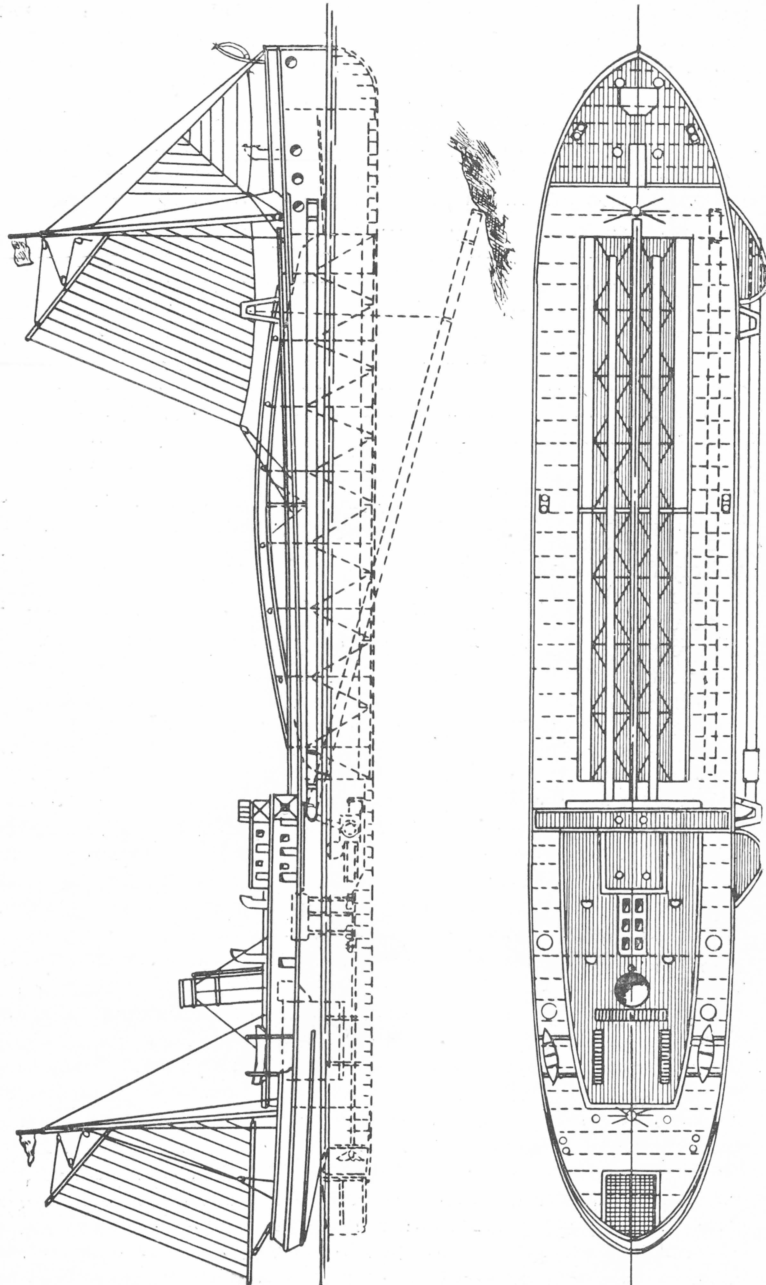

FIG. 151. GENERAL ARRANGEMENT SUCTION DREDGER.

are forward of the boiler, the reason of this being that the pumping machinery will be nearer the suction pipe discharge, and the arrangement of all the machinery is thereby made more compact. The following are the principal particulars of the "Coronation," another vessel owned by the Mersey Docks and Harbour Board :—

Length, between perpendiculars ...	332′ 0″
Breadth, moulded	52′ 9″
Depth, moulded	20′ 0″
Draught, maximum, loaded	17′ 3″
Propelling engines	2,000 I.H.P.
Cylinders	19″, 30″ and 49″ × 30″
Speed, loaded	10 knots
Loaded capacity	3,500 tons
Pumping machinery	800 I.H.P.
Cylinders	12″, 20″ and 32″ × 18″
Pumping capacity, per hour	4,500 tons
Suction pipes, two	36″ diam. 80 ft. long

A somewhat larger vessel belonging to the same Board, the "Leviathan," has rendered very good service, and the work she has done at the mouth of the Mersey has been to pump an average of over 11 million tons of sand per annum. This is a good record, and when it is seen that the vessel is capable of filling herself with 10,000 tons of sand in a matter of sixty minutes, and discharging herself in ten minutes, her rapidity and size fully warrants her name.

Our last type of dredger is the Suction Cutter dredger. After the general adoption of the suction dredger consideration was turned to the application of this type of appliance for the removal of harder substances. By directing strong jets of water, compact strata could be loosened or disintegrated, and it was anticipated that much valuable work could be executed by this method. Later rotary cutters were introduced, which although producing somewhat unsatisfactory results as far as soft clay, etc., were concerned, owing to the constant fouling and choking of the cutters, nevertheless proved to be useful for the removal of material which could be readily resolved into disintegrated particles. These types of dredgers have not been favoured by European owners, although they are used extensively in North and South America, probably because the discharge pipe can be of a great length, sometimes as long as 6,000 feet, and the dredged material can be utilised in the building up of river and canal banks, etc. The capacity of the cutter dredger is usually about 1,000 cubic yards of stiff clay per hour; and cases are on record of these dredgers picking up boulders weighing as much as 500 lbs. each; and discharging them along lengthy pipes without any apparent difficulty.

Hopper dredgers are frequently employed where it is required to have the dredging plant in one hull, and with the suction, cutter

and single chain bucket dredgers the hoppers are arranged amidships, each side of the centre line of the vessel, sufficient space being left between to allow for the dredging apparatus. With the grab dredger the hatches are usually small enough to allow the cranes being fitted on the deck each side of the hatches, at the forward and after ends. With the double chain bucket dredger, where the ladders are arranged longitudinally, the hatches and hoppers are as a rule, small, but are fitted in the centre line of the vessel. Hoppers are not treated in this chapter, but for information on hopper doors, etc., the reader is referred to Chapter 6 dealing with Hopper Barges.

The shape of the hull of dredgers are the "ship-shaped" and the "pontoon shaped." The latter is highly inefficient, except with stationary dredgers, and is seldom applied with self-propelled dredgers, even of the river type. The midship section is rectangular, and the shape is continued all fore and aft with no alteration, the ends being also rectangular. The other type seldom has a perfect rectangular midship section for, although the sides are straight and the bottom flat, some little curvature of bilge is given. The full section is carried well forward, owing to the loss of buoyancy due to the opening through which the ladder, etc., passes, and well forward the full U section is introduced. The after lines are necessarily full, but tend to sweep in a little to afford some efficiency in propulsion, and to reduce the resistances, which are very great owing to the body of water which is carried along with the vessel. The block coefficients are usually high, being generally between 0.70 and 0.92, although by making allowances for the loss of buoyancy, the coefficients are often reduced by over 15 per cent. There are many considerations in the construction of dredgers which require the most careful attention. The forward and after ends are quite easily arranged, and their construction closely follows that of the larger type of barge and lighter. With the midship portion, however, many difficulties present themselves. At the forward and after end of the opening, or well, through which the ladder, etc., passes, there must be fitted water-tight bulkheads, and unlike most bulkheads, they have the pressure of the outside water partly in direct contact with them. These bulkheads must have plating of very substantial thickness, due allowance being made of the fact that the exposed areas will be subjected to excessive wear and tear, and must be well stiffened by fitting deep angles or bulb angles, on the inner side. The stiffeners are well attached to the under side of deck and to the tops of the floors by deep plate brackets, and angles. The necessity of the efficient fitting of deep brackets will be seen later.

The well makes very considerable reductions in the longitudinal strength of the boat, since the centre, and perhaps two of the side keelsons, besides the garboard strake and keel, are stopped

short at the bulkheads, and the fullest compensation must be made. Two longitudinal bulkheads extend the full length of the well, and these make considerable compensation for the reduction of the longitudinal strength, especially if their strength be well scarphed to the fore and aft members of the ends. These bulkheads, which if possible should have their foot angle continued forward and aft in order that they may serve as the outside angles of a side keelson angle, are stiffened on the inside by angles of the same spacing and scantling as the ordinary frames. The attachment of the bulkheads to the deck and bottom plating must be rendered water-tight by fitting an angle at the join on the inside, and afterwards caulking it. These angles are attached to the stiffeners by angle lugs, and further attachment is made by fitting deep plate brackets to the bulkheads and the under side of deck, *i.e.*, by the beams, and to the floors.

Wherever possible, the transverse strength is preserved by fitting deep floors, and substantial frames in way of the hold in the side compartments, the frames being continued round to form the bulkhead stiffeners. When hopper doors are to be fitted this cannot be done, and other methods have to be resorted to. Strong beams must be placed at each end of the well, and if possible half beams in way of the length of the well, but if the latter cannot be done, quarter beams are adopted and deep beam knees give support to the deck stringer plate. The side stringers are continued all fore and aft, and they should be carried through the bulkheads, necessary forged and smithed angle collars being used to ensure water-tightness. If, however, they are stopped, large brackets must be fitted on each side of the bulkheads in order that the strength be continuous.

In many cases the length of the ladder or suction pipe renders it necessary to fit an open well, *i.e.*, extending forward to the bows. In this case no bulkhead is fitted at the forward end, the well being quite open, and the forward hull is, as it were, two hulls which are entirely independent of each other, and only connected together at the after end of the well by the usual bulkhead. When this arrangement is adopted, each hull can be built with its own transverse and longitudinal members, but care must always be taken to ensure that the otherwise two hulls are strongly and efficiently connected together by carefully interweaving the various members of their construction, and avoiding, wherever possible, any abrupt discontinuity of strength.

The shell plating needs special consideration and mention. The two strakes of plating, one on each side, adjoining the well, are in reality garboard strakes, and are usually very thick—thicker than would be required for the garboard strakes of a normal vessel of equivalent dimensions. These two strakes contribute in a large degree to the longitudinal strength of the vessel, and substitute the keel, garboard and adjacent bottom plates when the latter are interrupted by the well. When these plates are run into the

normal plating at one or each end, the thickness must not be abruptly reduced to what would be required for normal plating, and in practice they are not reduced more than 1/20th ins. in thickness towards the ends in small vessels, and not more than 2/20th ins. in large vessels where there is a considerable length of forward and after body. The bottom plating, including the keel (a flat plate keel is usually fitted to this class of vessel) and the garboards are of necessity, stopped at the well. The remaining strakes and the bilge strakes are of unusually heavy scantlings. If hopper doors are fitted, which are treated fully in another chapter, at least one strake of plating should be allowed on each side of the doors, and these should be exceptionally heavy, it not being uncommon to fit doubling strakes in way of all hopper doors.

The side plating, while not incurring so many demands as the bottom plating, is nevertheless of substantial thickness, and when it is remembered that the side plating must, to a degree, compensate for the discontinuity of the strength of the bottom, the need for exceptionally strong side plating will be evident. It is not unusual to fit doubling strakes to the sheer strake, this being an important member of the longitudinal girdering. If only a single plate be fitted, however, the thickness must at least be equal to the thickness of the garboards.

The construction of the deck, is important, but if care be taken with the general arrangements, little trouble will be caused in the provision of sufficient transverse strength. All beaming should be of a stout, strong nature, and wherever possible whole beams are fitted. However with the two hulls, previously referred to, the beams can be from the ordinary frame heads to the heads of the longitudinal bulkhead stiffeners, thus in reality, they are full beams. When these compartments are turned into hopper compartments, this becomes impossible, and only quarter beams, or according to the two hulls, half beams, can be fitted. This can only be accomplished with vessels of considerable breadth, and in order to afford the sufficient strength, the coamings of the hopper hatches must be continued below the deck sufficiently to allow the ends of the beams being well secured, and tied together, by angle lugs. Strong beams must be placed at each end of each compartment, and these are often of deep bulb angles, and where necessary, strong bulb angle beams must be interposed at regular and suitable intervals, in the length of each hopper hatchway. Necessary extra stiffening is always given to the decks under hopper winches, and dredger columns.

With the familiar ladder dredger, a crane must be supplied generally at the forward end, for raising and lowering the ladder. Many makes of special cranes are on the market, but it is not unusual to fit built-up cranes over the end of the well. These are built up of channel bars, usually two in number, which are

shaped horse-shoe fashion, the feet of which are forged into palms for fastening to the deck. These two bars, placed one behind the other, and each stepping over the well, are connected by another short piece of channel bar which carries the necessary sheaves, etc. Often to afford additional stiffening, and also to present a better appearance, the sides of the crane are plated. Suitable leads and sheaves, are fitted to the deck, for the chain lead to the ladder winch.

The tower which carries the upper pivot of the ladder is always constructed of iron or steel. It is framed with angles, channels, or other suitable sections, according to the length of the ladder, the height of the tower, and the average weight that it will have to support when the buckets are full. The tower must be suitably constructed at the top to allow for the carriage of the upper pivot, and necessary arrangements must be allowed for the discharge of the dredged material. If the tower be high, some diagonal bracing must be fitted, and in order to prevent any tripping of the tower, it is advisable to continue the corner frames, at least, down to the floors, and attach them to the keelsons, if possible, by large brackets. The whole tower is plated on the outside, and the plating should be of substantial thickness, especially if the buckets empty into the top of the tower, when with one or more shoots at the side, the wear and tear will be considerable. An inspection platform is usually arranged at the top, fitted on the outside of the tower, and supported by suitable bracket plates. An iron ladder leads to it from the deck.

With suction dredgers the pipe is generally arranged, with small vessels, to lie against the side of the outside plating. This method is advantageous as far as hold capacity is concerned, but the pipe is open to considerable damage. Some protection is afforded, however, when the side suction pipe is fitted, by building small platforms at the forward and after end of the parallel middle body, so that they come just above the ends of the pipe when it is raised above the water level. When the suction pipe is fitted, the crane is not so strong as that required for the ladder dredger, and generally closely resembles the gallows that are fitted to trawlers.

Owing to incompatible shape of the hull of dredgers, the resistances are very high, and the power required for propulsion is far greater than that required for vessels of normal shape with the same dimensions and speed. When the large well is fitted, a large body of water is carried along with the vessel, and besides the enormously increased wetted surface, there is a greater eddy-making resistance and a large proportion of the power is inevitably lost. This is not in so much evidence with the suction dredgers where the form of under water body is more compatible, and it is not therefore surprising to find that the later type of dredgers are less powered than the other types of equivalent dimensions

and speed. With the suction dredger the Admiralty coefficient varies between 130 and 155 according to the size and shape. Taking the "Coronation," see pp. 243 it will be seen that the coefficient is as follows :—

$$\text{I.H.P.} = \frac{D^{2/3} \times V^3}{C}$$

$$C = \frac{300 \times 1{,}000}{2{,}000}$$

$$C = 150, \text{ approx.}$$

With the ladder dredger, however, a different state of affairs exists, for taking a vessel of 1,400 tons displacement, fitted with engines developing 1,200 I.H.P., and driving the vessel at 10 knots, we get :—

$$C = \frac{1{,}400^{2/3} \times 10^3}{1{,}250}$$

$$C = \frac{125 \times 1{,}000}{1{,}200}$$

$$C = 104, \text{ approx.}$$

It will be seen that with ladder dredgers over 50 per cent. more power may be required to propel the vessel at the same speed than with the suction dredger. The speed given above, however, is high for this class of boat, since the resistances increase very considerably with speed, and it is usual for dredgers to be somewhat low powered. The average speed for dredgers is between 3 and 6 knots, for which the most economical power is required.

Chapter 16.

SHALLOW DRAUGHT VESSELS.

GENERAL.

No hard and fast rules can be laid down regarding the design of shallow draught vessels. The conditions of navigation vary on different rivers and generally a different type of boat is needed to navigate the upper waters of a large river than would be needed

on the lower part of the river, where the depth of water is greater and the channel freer. In many navigable rivers there are rapids where the current reaches a speed of 12 miles per hour, while in others the water carries so much mud and silt in suspension that old channels are often choked up, new bars formed, and the regular channel changes its position in an incredibly short time. It is evident that all these various characteristics in the rivers themselves will have some influence on the type of boat to be used and the kind of propulsion which must be adopted to give the most efficient service.

From the nature of the employment of the vessels everything must be of the most simple and efficient type, and, in this connection, the machinery must be treated equally with the hull. It should be borne in mind that the vessels will operate hundreds of miles from any repair shop, so that every precaution to avoid breakdown from any cause must be taken, and as nothing is perfect, breakdowns do occur, the designer must have ensured that replacement and repairs are as easy as possible and that no specially made parts, which cannot readily be duplicated, or fittings requiring material that cannot easily be obtained, have been embodied in the construction.

It is noticeable that the design of the hull of light draught vessels is very similar in a majority of cases. Bluff bows, wide sterns, flat bottoms and vertical sides are the main characteristics of the hull of this type. The draught is usually greater at the bow than at the stern. By allowing greater draught at the bow, steering is found much easier, and in the case of grounding, only the bow is affected and the vessel can usually be worked off by her own power. As the hulls are both broad and shallow, the principal weights are distributed as widely as possible, and the entire hull is thoroughly braced to supply the lack of structural strength in the hull itself.

With any boat built primarily to carry cargo, it follows that any improvement which reduces the profit-earning weight that can be carried must be of great value before its inclusion in the design can be justified. In very small vessels a serious increase in light draught is caused by the accumulation in the vessel of such things as paint drums, both full and empty, supplies of brasses and bolts, engine room tools and similar details. This, together with excessive spare gear, often accumulates to such an extent that tons of valuable freight paying cargo is unable to be carried. It is thus apparent that not only must weight be kept down to a minimum in the original design of the vessel, but during the existence of the boat, care must be taken to prevent the accumulation of material of doubtful usefulness.

It should also be noted that considerable weight can be saved in small details such as bollards, fairleads, stanchions, valves, beds, chairs, etc. Everything should be of the lightest pattern

consistent with sufficient strength. It should always be remembered that in the design of vessels of this type, the ultimate success of the vessel lies in the thoroughness with which unnecessary weights are omitted.

The propulsion of river steamers may be by one of the following methods :—

1. The side wheel paddle,
2. The stern wheel paddle,
3. The screw propeller,

and the vane wheel, particulars of which are given later.

The means of propulsion to be adopted in any case depends almost entirely upon the nature of the river on which the boat is to operate. All three systems are in successful use. The stern wheeler is used in preference to the side wheeler because the principal weights in such a vessel are so disposed that for equal strength of hull the weight of the material in the stern wheel boat can be less than in a side wheel of corresponding size. Moreover, the sternwheeler allows a smaller overall width, and this is frequently a factor of considerable importance where the width of channel is limited or where locks have to be negotiated. The use of screw propellers was not very general until the tunnel form of construction was invented and perfected, so that the screws could be protected from damage in case of grounding or of striking floating timber or rocks. There are many advantages to be gained by its use. Substituting screw propellers for stern paddle wheels permits a great reduction in the weight of propellers and shafting.

It is desirable to keep the machinery as simple and straightforward as it can be. Fuel economy is not generally so important as light draught and simplicity, and it is thus permissible to fit the less economical engine in favour of low initial cost, light weight and simplicity.

Considerable saving in weight can be made with the machinery. For instance, if the vessel is supplied with an extra large boiler for burning wood, it is quite unnecessary to fit forced draught for the purpose of burning coal. Forced draught is too violent for wood as fuel, and in any case the boiler would be big enough for coal without forcing. If the vessel is on service in fresh water and using cheap fuel, it is totally unnecessary to fit a surface condenser and corresponding pumps with the accompanying weight and expense. If a non-condensing engine be fitted, with the exhaust taken into the funnel, the boilers can be made smaller and lighter, due to the increased draught in the furnace. With the water-tube boiler also, considerable saving in weight can be made over the older return-tube boiler and also in the water it contains.

With all water-tube boilers fitted on paddle and stern wheel vessels, it is advisable, however, to fit an extra large steam drum

as it is found that the large slow running cylinders cause a pulsation on the flow of steam in the pipe, which in turn causes priming. A large steam drum holds more water, and there is thus a slight disadvantage from the weight point of view, but it provides a larger margin of fluctuation in the water supply and does not require such constant attention.

The increase of carrying capacity by the reduction of weight of hull and machinery can also be obtained by increasing the block coefficient, but in this connection it is necessary to proceed cautiously, particularly with bluff paddle steamers. In paddle steamers the entire weight of machinery and fuel is amidships, and if the ends of the vessel be made very bluff, the vessel will tend to sag and the deck buckle when the boilers and bunkers are full and the holds empty. It is necessary then to fit additional stiffening under the deck to resist the compression stresses, and it is doubtful if the gain in carrying capacity due to the increased block will compensate for the extra stiffening and complication in the holds.

As any increase in the block coefficient in shallow draught vessels is felt mostly at the ends, due to the full midship section and long parallel middle body, it is all to the good in stern wheelers, where the machinery is fitted at the ends, but in these vessels very little variation in the coefficient can be made. In the construction of shallow draught vessels, the necessity for simplicity should always be borne in mind, and great care should be exercised to ensure that the scantlings of all parts are of sufficient strength, yet not too heavy. The riveting should be arranged so as to have as few different sizes as possible, and when most of the work is to be riveted after re-erecting, the maximum size should be $\frac{3}{8}''$, so that hot riveting will not be required.

Very good results have been obtained by using unskilled labour in erection, and the watertight qualities of the hull have, generally, been exceptionally good when cold riveting has been adopted.

Considerable weight may be saved by the flanging of plates, where in ordinary practice angle bar connections would be used. For example, the floors can be flanged to the shell plating, the top of the floors can also be flanged, thus avoiding the use of reverse bars as shewn in Fig. 152. The weight of one bar flange is saved together with the rivet heads and points. The same thing can be applied to the lower edge of deck girders and also to side stringers at the midship portion of the vessel, as shewn on Fig. 153.

The steel work should be protected from corrosion by galvanising, and in this connection it should be noted that all flanging must be carried out first as the success of the flanging system depends upon the efficiency of the galvanising. Liners and packing should be avoided as far as possible, and in order to assure this, the frames and beams are generally joggled.

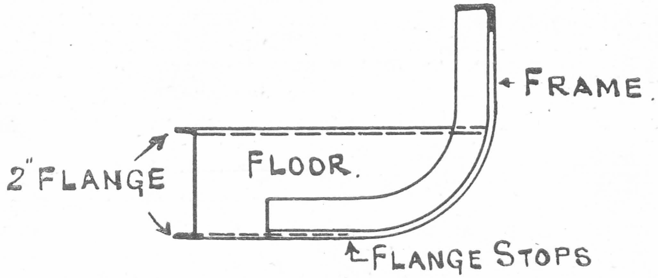

FIG. 152. FLANGED FLOOR.

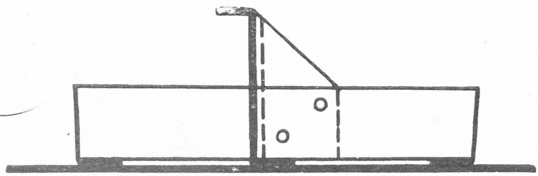

FIG. 153. SIDE STRINGER.

In considering the dimensions of a vessel, due regard must be given to the type of river which is to be navigated. The length is determined usually by the nature of the bends in the river. It is obvious that in a river which changes its direction abruptly, the steamer must be of such a length that she will easily pass round the bend without risk, and, further, the worst possible case must be considered. The length, being determined by local conditions, automatically fixes the breadth. Vessels of comparatively slow speed will be, approximately, four beams long, while, when higher speeds are contemplated, the proportion becomes six to one. The depth is approximately settled by the maximum draught permissible, plus the minimum freeboard that is considered safe.

A very usual and successful speed for ordinary small river boats is 10 miles per hour. This speed can generally be obtained with ordinary simple machinery. As the size of the vessel increases, higher speeds may be obtained up to 13 miles per hour in the larger steamers without unduly cutting weight in any part.

STERNWHEELERS.

The principal feature of the Sternwheeler is the position of the paddle wheel, and all other peculiarities of the design of this type of vessel are due to the engine having to be situated at the extreme after end of the vessel. The engine being so placed necessitates the boiler being put well forward in order to maintain an even keel, and this has the advantage that the entire midship

portion of the vessel is left for the stowage of cargo or passenger accommodation. On the other hand, however, the steam pipes require to be of abnormal length. Further, due to the two heaviest weights being placed at the extreme ends of the structure, and to the fact that these vessels are generally of small depth of hold, sufficient fore and aft strength cannot be obtained without constructing a certain amount of girder work above the level of the main deck, and this in some cases interferes with the free passage of cargo to and from the shore.

In the case of a sternwheeler, the light hull structure may be considered as a girder, loaded at the ends. The form of framing adopted for a stern wheel vessel with two decks is shewn in Fig 154a. In this case advantage is taken of the awning deck to raise the tension member of the girder so as to make it more effective. It is evident from the figure how the severe hogging stresses, when in light condition, are met.

The method adopted for a single deck vessel is shewn in Fig. 154.

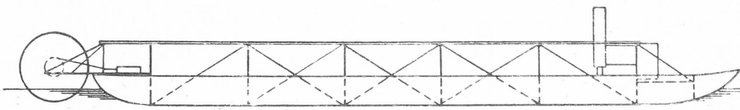

FIG. 154.

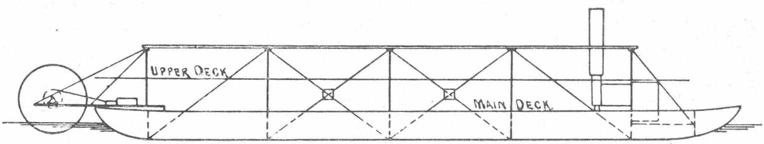

FIG. 154A.

Stern wheelers may be divided roughly into three classes, as follows :—

1. Very shallow draught vessels, a large number of which are built in this country for use on the rivers of Africa, India, etc., for the conveyance of passengers and cargo.
2. Vessels used on the Elbe and Oder in Germany for the towage of heavy barges mainly up stream.
3. Vessels used on the Mississippi, Ohio, etc., for taking tows down stream.

The vessels in class 1, above, are generally of galvanised steel of very light scantlings. The average light draught of these vessels is from 18″ to 24″, and the load draught is seldom much more than 3′ 0″. The main deck is often of chequered steel plates galvanised. The upper deck, when fitted, is supported on stanchions. An awning deck is sometimes also fitted. The shell

plating is about $\frac{1}{8}''$ thick, and is made slightly heavier at the bow in order to withstand all grounding and beaching strains.

The German vessels are essentially tugs and have no upper deck. They are built of steel and are of very shallow draught. The hulls are deep and sufficient longitudinal strength is obtained under deck to do without top bracing. The machinery is fitted below the deck and completely closed in. The wheel is also covered by a light casing.

The vessels in the third class are also tugs, but whereas the German vessels have to take the heaviest loads up stream, the American boats take theirs down with the current. With these American vessels, the load is pushed in front and the vessel is used principally as a rudder. The tow usually consists of from 16 to 24 coal barges all securely chained together, and the stern-wheeler is rigidly fastened to the stern of the tow. As the barges aggregate anywhere from 20 to 60 thousand tons in a single tow, the problem of steering demands serious consideration, and it is doubtful if any better form of propulsion can be devised than the old-fashioned, large, heavy stern wheel wood paddles which have proved so effective for this work. It is, of course, impossible to steer an unwieldy collection of barges straight ahead all the time, and these boats have to be constantly stopping and going astern to manœuvre their tow past the bends and other obstacles. It is said that these vessels are backing for about one-fifth of the time they are under way.

These vessels have generally only one upper deck, but the draught is, in some cases, as much as 5′ 6″. They are often built of wood and are much stronger than the usual type of shallow draught steamer. In the girder work above the deck in these vessels, the compression members are generally of wood and the tension members of chain.

The success of a stern wheel vessel depends upon the following factors :—

1. Correct design of hull lines at the stern.
2. Arrangement of the paddle wheel and rudders.
3. The structure provided aft for supporting the wheels and engines.

Generally the stern line in plan is square across the ship, the buttocks all rise up under the stern on the same curve, and since the midship section is more or less square, the bottom of the vessel rises up until it meets the deck; the side plating being tapered off accordingly. Success in the design of the stern is in the choice of the correct buttock line. If it is made too fine, a loss of displacement and longitudinal strength is incurred, and if too full, the flow of water to the wheel is interfered with, the effect of which is greater in going astern. For successful working the paddle wheel should be kept well aft, the forward edge of the floats being about 18″ from the A.P.

Sometimes two paddle wheels are fitted and the engine placed on the centre line between them. An extension of the hull is then built between the wheels, which gives additional displacement and strength underneath the engine. With the ordinary stern, without the extension, three rudders are generally fitted immediately forward of the wheel, and a very powerful steering effect is obtained both ahead and astern. The rudders are usually of the balanced type and are made of wood. When going astern all the water from the wheel is forced on the rudders, and when a steamer of this type runs her bow aground, it is possible by moving the rudders from port to starboard and back again to cause the stern to swing from side to side so that she gradually backs off.

The bow lines of sternwheelers vary from the usual ship-shaped bow with a straight stem to the full spoon bow with no stem at all. The spoon bow owes its origin to the lack of landing stages in the districts where the vessels operated. Vessels with a spoon bow could easily be run ashore and a gangway run out, while with the well rounded bearing surface there was little difficulty in getting off the bank. On a river with numerous turbulent rapids and cross currents, it was found that the spoon bow was very successful in holding her course when meeting the rapids at an angle while rounding the bend. The ordinary bow is adopted where a finer entrance is desired, where much turbulent water is not encountered and where speed is more important than actual minimum draught. It gives good steering power when steaming ahead in smooth water.

The structure provided aft for carrying the wheel is sometimes built up as an extension of the side plating and the girders in the hold. A simpler manner, however, is to have channels fitted on top of the deck and overhanging sufficiently far to take the main bearings. These channels should be straight throughout, as it makes the lining up of them comparatively simple, and this is desirable as cylinders, guides and main bearings are all fitted to them at different points in the length. At the after end of the hull a vertical strut is erected in line with the engine beams, which carry the main bearings and a diagonal tension rod with tightening screw is fitted from the top of the strut to the outer end of the engine beams. A second tension rod is sometimes fitted to the beam just forward of the main bearing. The top of the strut is also secured to the main girder and to the deck by angle bracing. It is of extreme importance that these tension rods be properly adjusted, as it is on the adjustment that the fore and aft and athwartship alignment of the main engines depend.

The longitudinal strength is maintained by the sides of the ship and by forward and aft lattice girders built in the hold. A solid bulkhead is often fitted the whole length of the ship on the centre line, and frequently, in addition, partial bulkheads are fitted at the sides. The depth of the hold is so small in proportion to the length that it is necessary to stiffen the structure by other

means. How this is done has already been referred to and is indicated in Figs 154 and 154a. At intervals along the deck, on both sides, vertical struts are erected and carried down through the deck and secured to the floors. Where possible they should be attached to the transverse bulkheads. The tops of the struts are generally connected to the stringer plate of one of the top decks, and this forms the tension member of a lattice girder. Diagonal bracings of angle or rod are fitted between the struts. The girder work must be sufficiently long to support the two main weights, the engines and boiler; and it thus extends from the rod supporting the wheel to forward of the boiler. It is advisable to fit one of the girders in the hold in line with the main engine seat beam which carries the bearing.

The design of the longitudinal girder should receive careful attention, and the system of making the main diagonal bracings of rods with tightening screws is finding favour. As all shallow draught vessels work to a maximum draught and not a mean, it is obvious that if the vessel is to carry her maximum deadweight at any draught, she must be flat on the bottom and neither hogged or sagged. For, if the vessel hogs up even, say, 1″, the ends of the vessel will be at the maximum permissible draught before the midship portion and a certain amount of cargo will then be shut out. When the main girders are fitted with adjustable tension rods, the general shape of the hull can be adjusted as required.

The types of engines fitted in sternwheelers varies greatly. In the Mississippi vessels low-pressure non-condensing engines are adopted, while with the German steamers the modern high-pressure triple-expansion engine is fitted. In the early days of shallow draught steamers the propelling machinery consisted of a horizontal engine with one cylinder on each side of the vessel, but modern practice with British engineers favours compounding when the length of connecting piping between the cylinders acts as a receiver and tends to steady running. The arrangement is very simple and all parts are easily accessible. The triple expansion engines on the German vessels are always fitted on the centre line. The indicated horse-power in some of the large vessels is as much as 750. High pressure superheated steam is used. The wheels in these vessels are small in diameter, run at a high speed, and are of steel with feathering floats.

The engines on the American vessels are usually placed at the sides of the vessel, with a single wheel between them. The stroke of the piston is very long and the connecting rods are generally of wood and from four to five times the length of the stroke. The paddle wheels are of wood, of very large diameter and heavy scantlings.

The radial type of wheel should be fitted in cases where the wheel is liable to damage by floating obstructions or grounding, as it is simpler to repair, but where there is a possibility of being

more than usually immune from such accidents it is advisable to fit a feathering wheel. One of the greatest advantages due to fitting a feathering wheel is that a smaller diameter is permissible running at a higher speed, and thus the engine may be lighter and with a shorter stroke.

The floats are usually of American rock elm, although teak is sometimes used. The efficiency of the wheel depends upon the immersion of the lower edge, which, of course, cannot be altered as the steamer proceeds on her voyage and loads or discharges cargo. It is usual, however, to arrange that the floats can be "reefed" in towards the centre of the wheel in the high-water seasons to permit of deeper loading without drowning the wheel.

The general arrangement of a stern wheel vessel built for service in the relatively shallow waterways of Egypt is shown in Fig. 155.

As will be noticed from the general arrangement, ample spaces are reserved for Native and European crews, with a separate galley for each. Space is afforded amidships for cargo with a 16′ × 12′ hatch on the Main Deck.

Separate cabins are fitted for Captain and Officers, with mess room, bath, showers, w.c.'s, etc. Cabins and decks are constructed of teak.

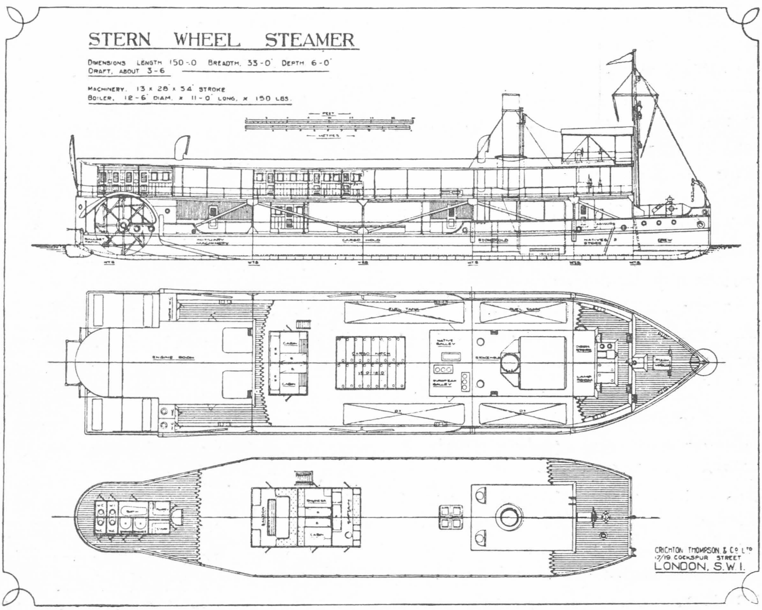

Fig. 155. General Arrangement Stern Wheel Vessel.

Ample store rooms and spaces are arranged in deck houses and elsewhere, as shown. All deck machinery is steam operated.

Fig. 155a. shows this vessel under construction at the Saltney Shipyard, Chester.

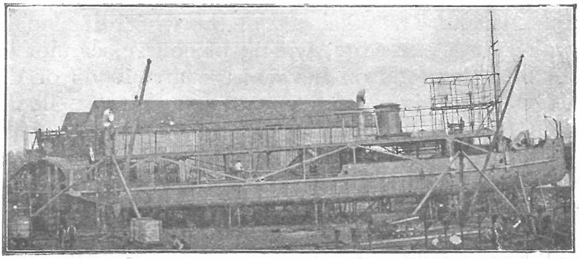

FIG. 155A. STERN WHEELER UNDER CONSTRUCTION.

The principal particulars of this vessel are as follows :—

Length B.P.	150′
Breadth mld.	33′
Depth mld.	6′
Draught aft and forward	3′ 6″
Displacement	318 tons
Block coefficient	.65
I.H.P.	450
Speed (about)	9 knots

The displacement is made up as follows :—

Hull and equipment	183 tons
Machinery	110 ,,
Oil fuel	20 ,,
Miscellaneous	5 ,,
Total	318 tons

The propelling installation comprises two sets of compound surface condensing stern wheel engines, having cylinders 13″ and 28″ by 54″ stroke, developing 450 indicated horse power, exhausting into a common condenser. Amongst the auxiliary machinery may be mentioned a duplex feed pump, two duplex general service pumps, hot well tank and feed filter, usual air and feed pumps, a three-ton Weir evaporator, a 30-gallon per hour Weir distiller, etc. Electric lighting is fitted throughout.

Steam is supplied by a marine return tube boiler, 12′ 6″ diameter by 11′ long by 150 lbs. working pressure, operating under forced draught, the heating surface being 1,800 square feet.

There are two paddle wheels, each 14′ external diameter, with 8 floats 7′ 6″ long by 2′ wide.

Sections in hold and in forecastle are given in Figs. 156 and 157.

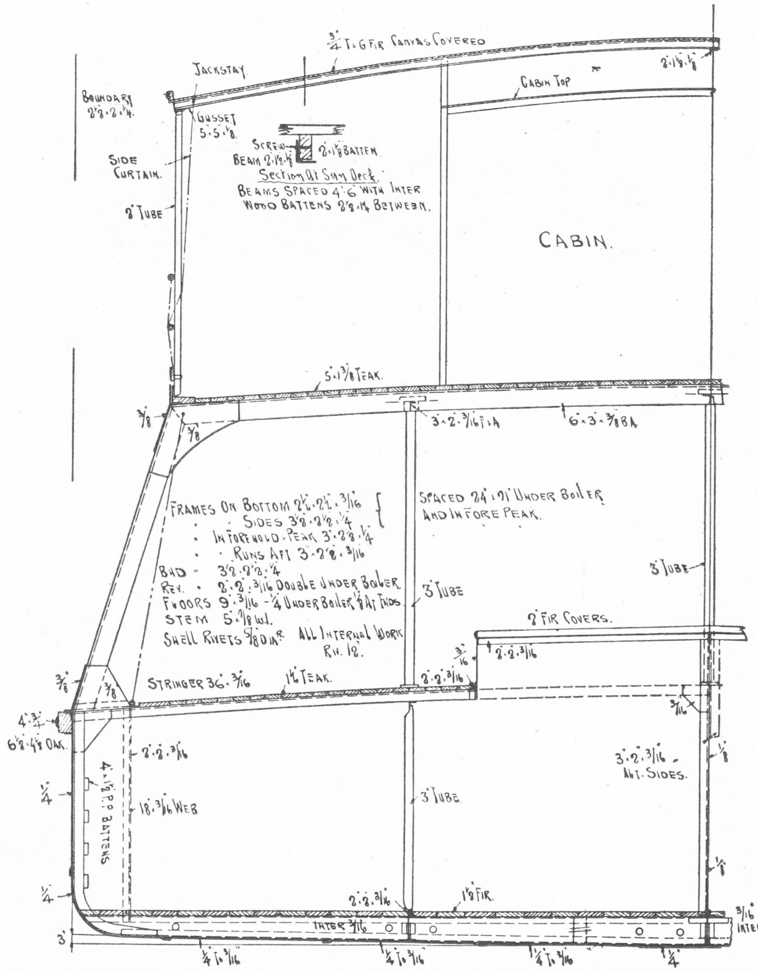

FIG. 156. SECTION IN HOLD.

The body plan and after lines of this vessel are given in Figs. 158 and 159. The sheer forward is 1′ 6″.

TUNNEL VESSELS.

The light hull structure of a tunnel boat may be considered as a girder loaded more or less at the centre.

With the screw vessel it is possible to do away with the system of cross bracing as adopted in Sternwheelers, and the problem of design is thus totally different. The ends of the vessel are buoyant and the stresses are generally distributed by means

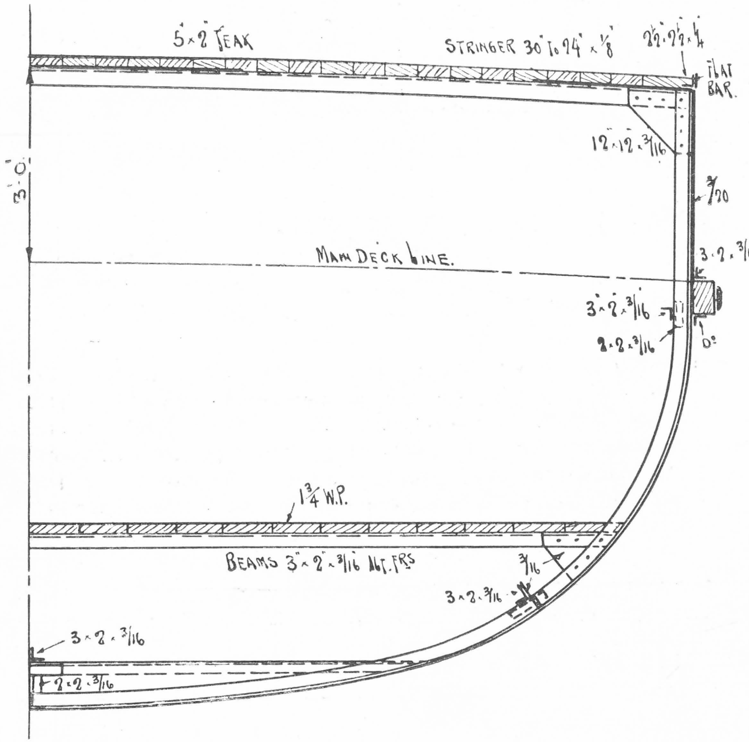

FIG. 157. SECTION AT FORECASTLE.

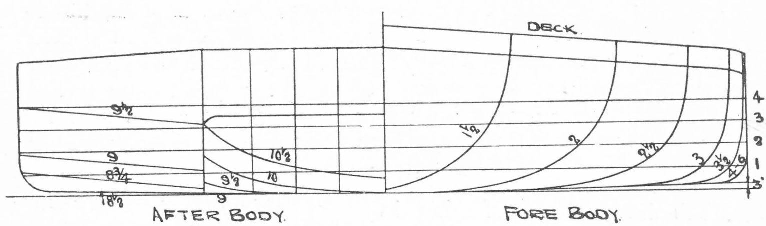

FIG. 158. BODY PLAN OF STERN WHEELER.

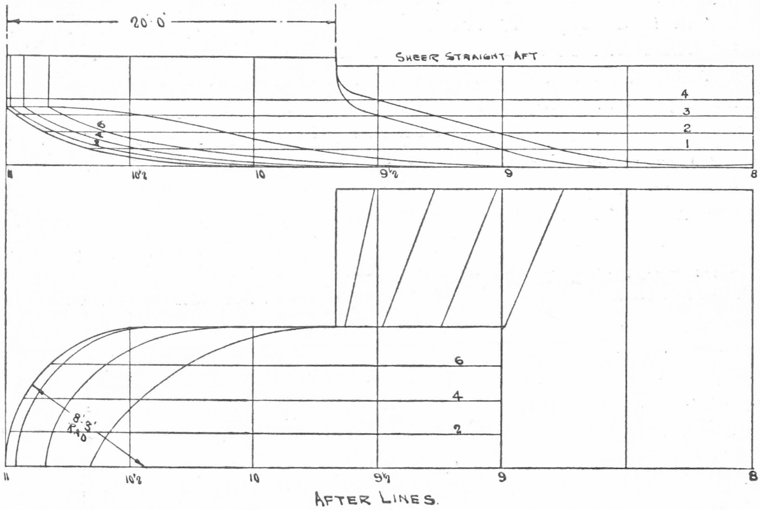

FIG. 159. AFTER LINES OF STERN WHEELER.

of longitudinal bulkheads and girders. The girders carrying the decks are incorporated with the deck-houses, as shown in Fig. 160, and the whole forms an exceedingly stiff girder. The sagging stresses due to the weight of machinery amidships are distributed towards the ends, and in the light condition the entire structure of the vessel takes a share in supporting the concentrated weight.

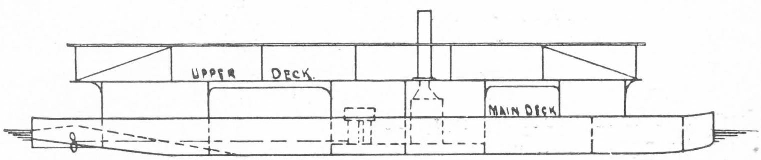

FIG. 160.

The screw in tunnel system of propulsion is the most up-to-date, and under certain conditions, results have been obtained which are far superior to those of the side paddle or sternwheeler. In order to obtain and keep a tunnel full of water, high revolutions are necessary, and this permits the use of a high speed light steam engine where economy is greatest at from 150—200 revolutions per minute. This in conjunction with a water-tube boiler gives a comparatively light propelling machinery.

When a vessel is designed to carry cargo, the draft is constantly varying, and it is here that the screw in tunnel vessel fitted with the Yarrow hinged flap has a great advantage over the side

paddle and stern wheel type of vessel, for it is apparent that in either of these types of vessels, the floats at one period would be too much immersed and at another too little immersed to get the best results. All the advantages are not with the tunnel boat, however, as it compares unfavourably with the paddle and the sternwheeler in going astern and in pulling up quickly. This, of course, is an objection to the screw vessel when trading on a river which is intersected with sand banks and narrow channels.

The use of screw propellers for the propulsion of shallow draught vessels has been investigated very thoroughly by Yarrow & Co., Ltd., Scotstoun, and the results of the investigation were embodied in a paper read at the forty-fourth session of the Institution of Naval Architects by Sir A. F. Yarrow. The following information is quoted from the paper, and, although perhaps to many it is familiar, yet it gives a good idea of the design, construction and efficiency of this type of boat, and is well worth keeping in mind in considering the shallow draught boat problems :

Referring to Fig. 161, this represents a section through one such as we frequently build. The upper part of the tunnel is considerably above the water-line, thus enabling the diameter of the propeller to be greater than the draught of water. We adopt, for example, in a boat drawing a foot, propellers of $2\frac{1}{2}$ ft. diameter, and in a vessel drawing 2 feet, propellers of $4\frac{1}{2}$ ft. to 5 ft. diameter. When the vessel is at rest the water level inside the tunnel is naturally the same as it is on the outside; but, when the propeller begins to revolve, the air which is enclosed in the upper part of the tunnel is forced out and replaced by solid water. By this means it will be seen that a large propeller, capable of utilising considerable power, can be used in combination with a shallow draught. There will be an increased resistance to the forward motion of the vessel, due to the action of the screw in reducing the pressure of water at the inclined part of the tunnel forward of the propeller, and this increased resistance is common, more or less, to all screw ships, but it is probably proportionately greater in this class of vessel than in those where the propeller is in the usual position. There is also a loss of efficiency due to the resistance of the inclined surface of the tunnel aft of the propeller.

The inclined portion of the tunnel aft of the screw should be as nearly horizontal as possible, so as to diminish this resistance; but this would increase the length of the tunnel and involve greater draught, because to augment the capacity of the tunnel below the water-line is just so much loss of displacement, and the water in the tunnel above the water line is equivalent to just so much load carried when the boat is at rest and the tunnel full. It is, therefore, desirable to reduce the capacity of the tunnel to a minimum, as considerations of draught render it sometimes impracticable to select a favourable inclination at the after part of the tunnel without causing losses, such as those

alluded to above, which may be even greater than if a steeper inclination of tunnel be adopted. The tunnel is sealed on all sides, this being necessary, because, when once the air is forced out, it must never be allowed to pass in, or the propeller would not be working in solid water. As regards the forward part and the sides, there is no difficulty in sealing the tunnel satisfactorily, but the extreme after part of the tunnel should be arranged to come two or three inches below the water-line, *i.e.*, sufficiently below the surface to exclude the air. To make the operation clear, I would draw your attention to the model, showing the after part of a launch. This, however, does not demonstrate the system favourably, because the boat is at rest, and the sweeping away of the bubbles of air is not so rapidly effected as when the boat is moving; in fact, in actual full size examples the action of expelling the air is almost instantaneous. It will be seen that when the motor driving the screw is set in motion, the air is driven out of the tunnel, and the propeller then works in solid water.

Above the screw, at the highest part of the tunnel, is a door which enables access to be obtained to it with very little difficulty. On one occasion we tested the time taken in changing a propeller on one of our gunboats, and it was removed and replaced by another in twenty minutes, while the vessel was afloat. The propeller, when working in a tunnel enveloped all round, is not so liable to damage as if it were at the stern in the usual place.

It has been stated that the vessels "Sheikh" and "Sultan," which we built in this manner for the Nile, did not tow efficiently, and that the sternwheelers, which we and other firms built for the previous Nile expedition, towed better. That was no doubt perfectly true, and may lead to the impression that vessels built on this plan are not efficient for towing. Such, however, is not the case. As a matter of fact, they are very efficient for towing, provided the propellers are made sufficiently large. With a view to securing the maximum efficiency for speed when not towing, the propellers in all these boats were made of small size. Had the "Sheikh" and "Sultan" been intended for towing, we should, no doubt, have adopted propellers of a diameter at least 50 per cent. greater than we did. I mention this fact, in passing, to avoid the impression that vessels on this plan do not tow well.

I now come to a departure which we have recently made in the design of these tunnel vessels, and which has added considerably to their efficiency. It will be remembered that the after part of the upper portion of the tunnel, which is inclined downwards towards the stern, is a source of resistance. As already explained, it is compulsory when starting that the after extremity should be below the water in order to prevent air gaining access to the interior of the tunnel. Now, experience has shown that once the boat is under way the after extremity of this tunnel, when full, may be above the surrounding water, because the rush of water

out of the tunnel in a sternward direction is such as to prevent the air passing in; in fact, the after part of this tunnel may be 6 or 8 inches higher than the water level without risk from this cause, at the same time improving the result, due to reduced resistance of the inclined surface. It has been shown that the after part of the tunnel should be below the water-line when the vessel is starting light; but if it were fixed in that position it would be unnecessarily low down when the vessel is loaded, thereby involving greater resistance than if the after part of the tunnel terminated at a level sufficient for the loaded boat.

In our more recent vessels of this kind, we have made the upper part of the tunnel, from the propeller to the stern, hinged in such a way that it can be raised and lowered to any desired height, either by mechanical means or automatically. Figs. 161 and 162 fully explain the system. Fig. 161 shows the position of the hinged top, or flap, when the boat is light, drawing 11 in., and Fig. 162, when the boat is loaded, drawing 28 in. It will be seen at a glance that when loaded, if the after extremity of the tunnel were in the same position as it is when light, it would involve a greatly increased resistance, while by raising the top of the tunnel the water has a clear passage open to it to freely pass away in an opposite direction to that in which the vessel is travelling. The gain by the raising and lowering of this flap is illustrated by diagrams in Figs. 163 and 164. When the launch is light, drawing 11 in. with the same power, the speed is increased from 9.2 miles an hour with the flap down to 10 miles an hour with the flap up; and when the draught is 28 in., loaded with 20 tons, the speed is increased from 6.9 miles an hour with the flap down to 8.25 miles an hour with the flap up, the power at both speeds being the same. As might naturally be expected, the increase of efficiency due to the lifting of the flap is greater when the boat is loaded, the lower speeds in both cases being what they would have been if there had been no adjustable flap, clearly showing the advantage of the flap.

Now I propose to describe a set of experiments carried out with a view to test the towing efficiency of this method of propulsion. We built for the Trent Navigation Company a twin-screw tug called the "Little John." It was 80 ft. in length by 14 ft. 6 in. beam; minimum draught, with steam up 22 in.; displacement about 40 tons. Each screw was driven by a single inverted engine, 10 in. in diameter by 10 in. stroke; high pressure, locomotive boiler. The dimensions of the tug were determined by the size of the locks and the depth of the river.

Up to the time of our building this boat the Trent Navigation Company had experienced much difficulty in dealing with their traffic. Side-wheelers were found too wide to pass through the locks owing to the paddle-boxes. A twin-screw boat with propellers in the usual position proved very inefficient; a stern-wheeler

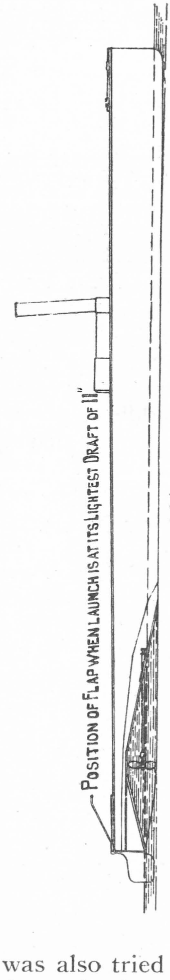

Fig. 161.

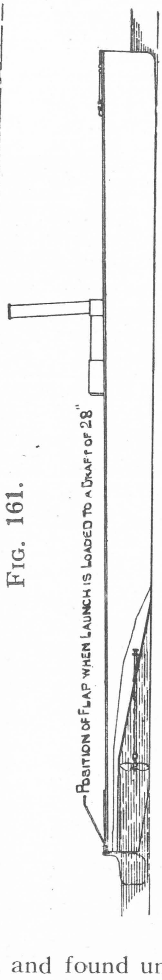

Fig. 162.

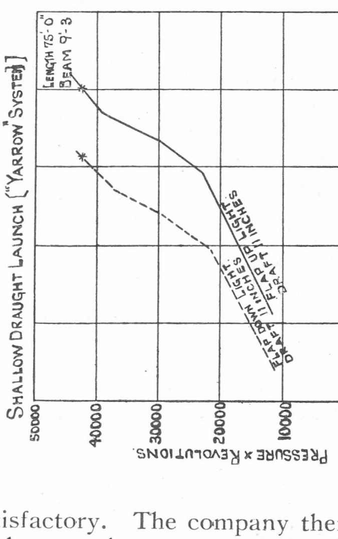

Fig. 163.

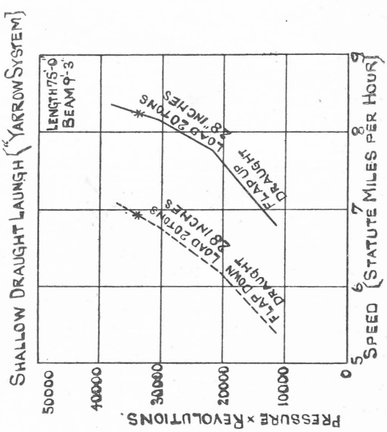

Fig. 164.

was also tried and found unsatisfactory. The company therefore determined to make a trial of the tunnel system, and the "Little John" was built. She has been in constant work for several months, and has proved conclusively that this system of propulsion is well adapted for towing purposes, enabling a considerable amount of power to be obtained and efficiently utilised in a small boat with a very limited draught.

Through the kindness of Mr. Rayner, the engineer of the Trent Navigation Company, an excellent comparison was made between our tunnel tug the "Little John," and a side paddle tug, the "Robin Hood," which the company have for towing on the lower part of the river below the locks, where the river is deeper. This latter vessel had feathering floats, machinery by Penn, and

was undoubtedly a good example of this type of vessel, considering the size, draught and power. She had a length over all of 91 ft. 6 in. by a beam of 14 ft.; breadth over paddle boxes 24 ft., draught 3 ft., displacement about 55 tons; two cylinders 18 in. diameter by 27 in. stroke, condensing; wheels 9 ft. 2 in. over the floats, 3 ft. 10½ in. wide; return-tube marine boiler. It will therefore be seen that the "Robin Hood" made a fair comparison with the "Little John."

In order to test the comparative efficiencies under ordinary working conditions, we towed a number of barges, first with one tug and then with the other, over the same reach of the river, indicating the engines at different speeds, and by means of a dynamometer obtaining the pull on the tow rope. The horse-power ascertained by the pull on the tow rope, and the speed through the water would be less than the indicated power of the engines by the loss due to the propellers (whether paddle or screw), the friction in the machinery, and to the power absorbed in driving the tug itself. The barges towed were :—

Barge.	Cargo.	Wgt. of Barge.
Severn	57 tons	20 tons
Royal Sovereign ...	50 ,,	15 ,,
Victory	50 ,,	15 ,,
Congo	Nil.	20 ,,
Crane Boat No. 1	5 ,,	15 ,,
Total	162 tons	85 tons
Grand Total		247 tons

The results are given in the Table herewith :—

Towing Experiments with Tugs "Robin Hood" and "Little John,"

with a view to test the relative efficiencies of the two systems of propulsion.

	I.H.P. of Engines.	Pull on Tow Rope, Lbs.	H.P. at Rope.	P'centage of Power of Machinery utilised in Towing.	Speed (Miles) per hour.
Robin Hood ...	90.2	2,314	31.6	35.0	5.12
	49.98	1,741	20.0	40.0	4.31
Little John ...	118.24	2,901	44.1	37.3	5.70
	94.37	2,321	32.3	34.2	5.22
	61.97	1,823	21.3	34.4	4.38

From these experiments and other data it was found that the proportion of the power of the engine utilised in towing is very nearly the same in both cases. The paddle boat is superior to the screw at low speeds and the screw better than the paddle at high speeds. On the average there does not appear to be any appreciable difference. It must, however, be borne in mind that one boat conforms to conditions of draught and dimensions which the other boat does not, the over-all dimensions and draught of the "Little John" enabling her to pass through locks and over shallows which the "Robin Hood" could not.

In considering the question of towing on canals or shallow rivers, it is not unreasonable to assume that the screw working

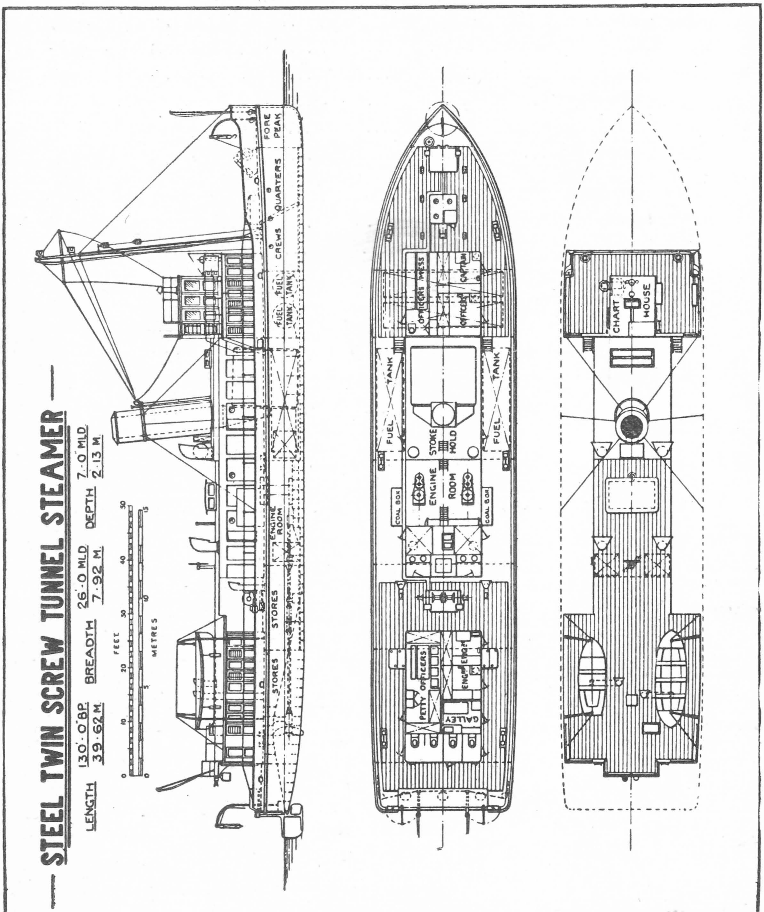

FIG. 165. GENERAL ARRANGEMENT OF TWIN SCREW TUNNEL VESSEL.

in a tunnel damages the banks to a minimum extent, and in this respect is better than the paddle or even a screw in its usual location; because with the propeller working in a tunnel, the rush of water being in an inclined direction towards the bottom, rather tends to scour it and to keep open the course, while with paddles the effect would be rather to disturb the banks and to cause the earth that is washed away from the sides to settle in the middle.

The general arrangement of a twin screw tunnel steamer is shown in Fig. 165.

The principal particulars are as follows :—

Length B.P.	130′ 0″
Breadth mld.	26′ 0″
Depth mld.	7′ 0″
Draught aft and forward ...	3′ 6″
Displacement F.W.	241 tons
Block coefficient	.73
Tons per inch	6.5
I.H.P.	450
Speed	$9\frac{1}{2}$ knots

The displacement is made up as follows :—

Hull and outfit	131 tons
Fuel and water tanks	7.75 ,,
Machinery, steam up	75 ,,
Electric light installation ...	2.25 ,,
Total light ship	216 tons
Deadweight : Oil fuel, water crew and stores	25 ,,
Total	241 tons

The propelling machinery consists of a twin set of compound surface condensing engines, 11 in. and 22 in. by 15 in. stroke, steam being supplied by an oil-fired and force draught boiler 12 ft. diameter by 10 ft. 9 in. long, with a working pressure of 160 lbs. The heating surface is about 1,600 sq. ft. A speed of $9\frac{1}{2}$ knots was obtained on trial, the trial draught being 3 ft. 8 in. Included in the auxiliary machinery is a general service pump, an evaporator and distiller, electric light installation, etc. The deck machinery is steam operated.

The propellers are three bladed, 5 ft. 5 in. diameter, and 7 ft. 6 in. pitch.

Construction sections of this vessel are given in Figs. 166 and 167.

A body plan and sketch of after end are given in Figs. 168 and 169. The sheer forward is 1 ft. 6 in.

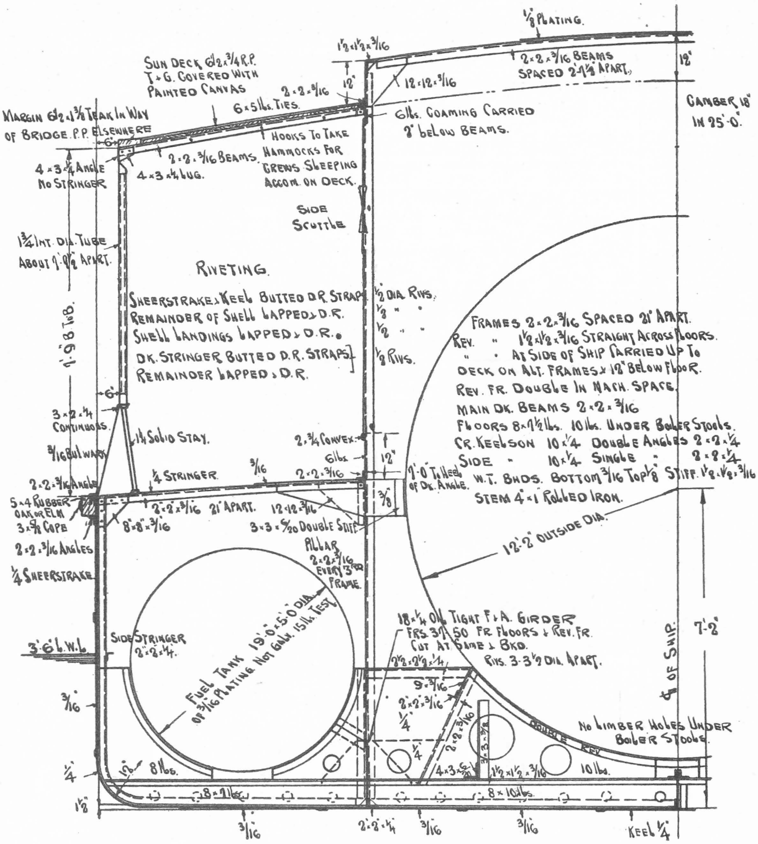

FIG. 166. SECTION IN WAY OF BUNKER.

VANE-WHEEL PROPULSION.

The need for shallow draught in ships produces a series of difficulties to the effective use of the engine power of a ship, and it is therefore not surprising that the question has received the attention of a large number of inventors.

Messrs. Wm. Denny & Bros., of Dumbarton, have introduced a new solution to the problem of efficient propulsion with shallow draught, by the introduction of what is termed "vane wheels." A paper on "Vane Wheel Propulsion" was read by the chairman of above company, Maurice E. Denny, Esq., at the sixty-sixth session of the Institution of Engineers and Shipbuilders in Scotland, and the following information has been taken from it.

A vane-wheel is composed of two or more helical surfaces or vanes attached to arms having the desired helical pitch, the axis

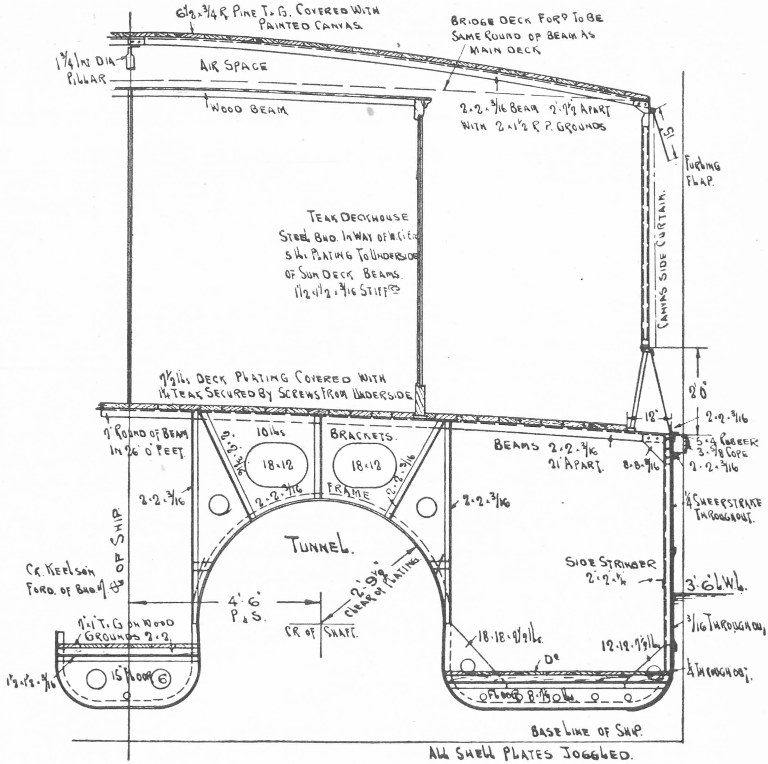

FIG. 167. SECTION IN WAY OF TUNNEL.

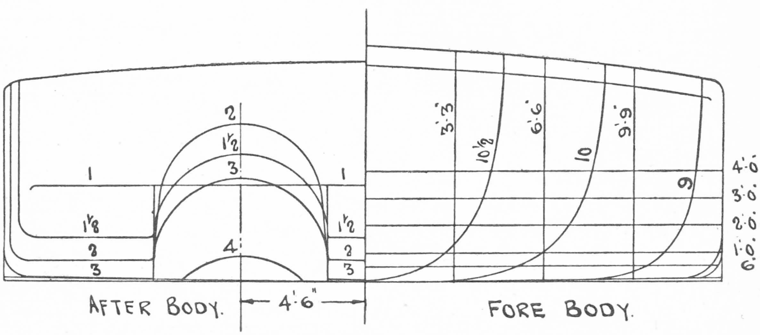

FIG. 168. BODY PLAN OF TUNNEL STEAMER.

of revolution being substantially fore and aft, and the diameter such that only the vanes are immersed in the water when propelling a ship. The axis of rotation is, therefore, well above the water. See Fig. 170.

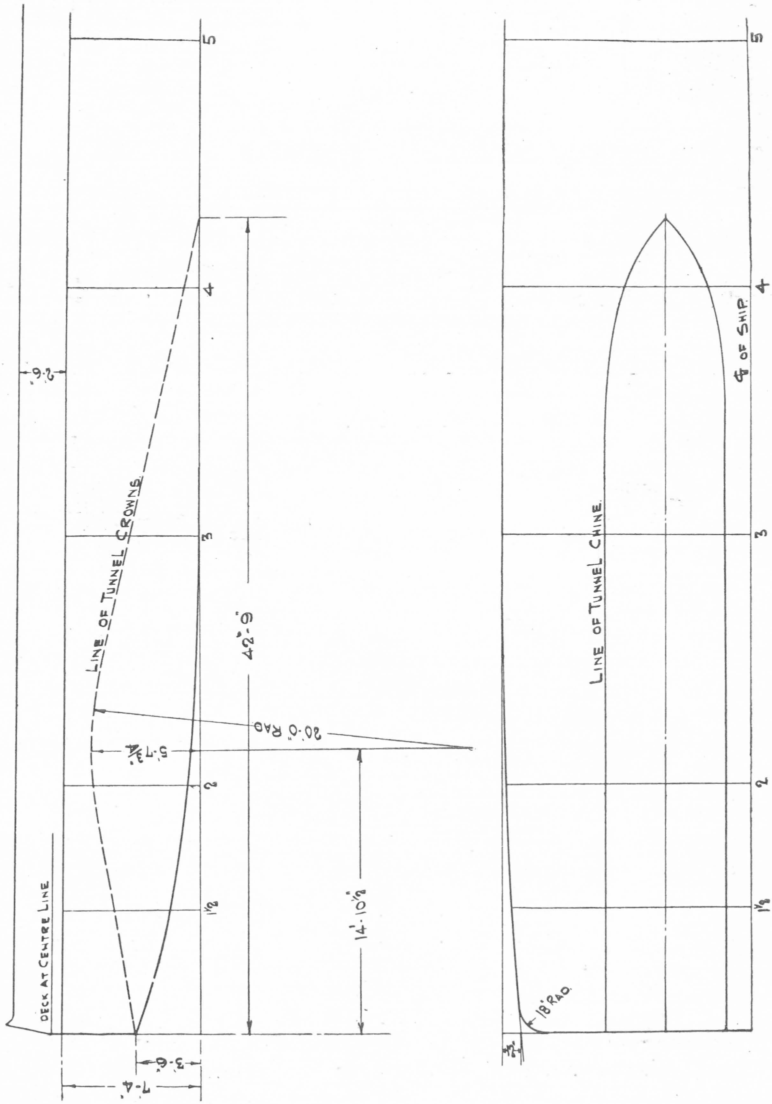

FIG. 169. AFTER END OF TUNNEL STEAMER.

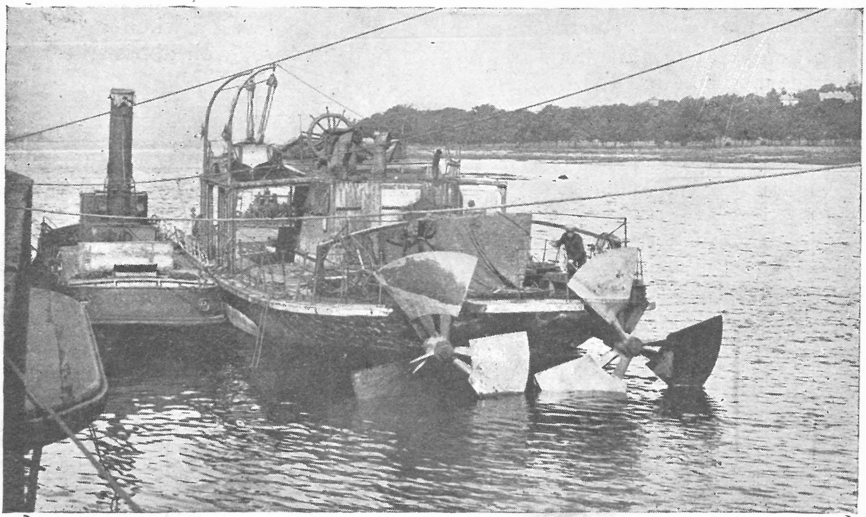

FIG. 170.

On the experimental boat, the vane wheels take the form of large curved plates like the tip of a propeller blade, but with straight sides, and a circular outside edge. These vanes, three in number, are each riveted to two arms, which are part of the hub. In order to avoid any undesired steering effect, the two vane wheels have identical dimensions and are symmetrically placed on the hull of the ship. One wheel is right-handed and the other left-handed, and they are rotated in opposite directions, so that the transverse thrust of each vane is balanced by that of the other when they are driven at the same speed. The wheels are placed side by side abaft the stern of the ship.

Tests have been carried out on a twin screw boat of shallow draught, and the particulars of the vessel and results obtained are as follows :—

Length	... ...	100′
Breadth	... ...	23.5′
Draught	... ...	
	Ford. 4′ $5\frac{1}{2}$″	
	Aft 4′ 8″	
Mean, 4′ $6\frac{3}{4}$″		
Displacement	... ...	186 tons
Speed	... ...	9 knots

	SCREW PROPELLERS.	VANE WHEELS.
Diameter	4 ft.	11 ft.
Pitch	5 ft. 8 in.	16 ft.
No. of Blades	3	3
Total Projected Area of Blades	10.2 sq. ft.	—
Immersion of Tips in Still Water	$3\frac{7}{16}$ in.	
Revolutions per Minute ...	226	66
Total Sectional Area of Water acted upon when at full speed	25.14 sq. ft.	59.28 sq. ft.
E.H.P. of Naked Hull	77.5	77.5
S.H.P.	197	116
Efficiency, *i.e.*, $\frac{\text{E.H.P.}}{\text{S.H.P.}}$	.394	.67

A temporary arrangement was employed for driving the vane-wheels by leather belting from the main engines.

It will be observed that the vane-wheels gave the same speed as the twin screws with 41 per cent. less shaft horse-power.

The propulsive efficiency of the twin-screws was rather low, though the resistance of the shaft brackets and projections (in this case amounting to 12 per cent. of the E.H.P. of the naked hull), together with the effect of the small immersion of the tips of the propellers, would probably not permit of a much higher efficiency being obtained.

Various facts account for the high propulsive efficiency of the vane-wheels.

The hubs of the vane-wheels are out of the water and, therefore, involve no extra resistance, as in the case of ordinary screw propellers. Vane-wheels do not require any immersed supports, as in the case of twin screws. Every portion of the immersed vane is acting efficiently during its passage through the water, being superior to paddle floats in that respect. Vane-wheels can be, and are, more favourably placed in relation to the flow of water around the hull than is the case with ordinary screw propellers or with stern paddle wheels.

The advantages claimed for the twin vane-wheel method of propulsion are as follows :—

(1) High propulsive efficiency in relation to all other known methods of propulsion.
(2) Great manœuvring powers.
(3) Effective variation of water acted upon with variation of draught, and therefore a variation of the thrust required.

(4) Higher revolutions per minute than either side paddle wheels or stern paddle wheels, and therefore less weight of machinery.

(5) With vane wheels abaft the stern of the ship the overall width is less than that with the side paddle wheel method; there is also less overall length of ship and wheels than in the stern paddle-wheel method.

(6) The wheels are stronger and lighter than either side paddle wheels or stern paddle wheels.

TRIAL TRIPS OF SHALLOW DRAUGHT RIVER STEAMERS.

The following notes on the trial trips of shallow draught river steamers, taken from "Engineering" by the kind permission of the Editor, are of interest.

In this country trial trips as a rule are run by an expert with the assistance of a recording party, all having considerable experience in the work required to be done, but in the case of vessels built or re-erected abroad the whole work usually falls on the engineer in charge alone. As the results of the trials of these vessels are usually sent home to the builders, and used as data for future designs, great pains should be taken to make such data as accurate and complete as possible.

The greatest difficulty is to record a correct speed owing to the varying strength of currents and tides and to the great speed of current flowing in some tropical rivers, and the first step towards accuracy should be to examine and check the measured mile course.

The speed of inland vessels is usually taken in miles per hour, instead of knots, and the distance between the posts should be a full mile if possible, not a half mile only. Care should be taken to ensure that a vessel on the course is running exactly with or against the current, as it is obvious that if there is any cross current acting on the vessel a certain amount of helm must be carried to counteract its effect, with the result that the speed will be reduced. The actual setting out of the mile posts should be done by a properly qualified surveyor, and, if possible, the distance should be checked by a Port or Government authority, as this is often of advantage in case of disputes. The mile posts being accurately, set out and certified, the course should be laid out and properly marked so that it can be easily picked up when required.

Considerable practice is usually necessary in running over a measured mile course in order to run as straight as possible and also to keep the course parallel to the posts. Practice is also necessary in making the turns, especially at the mouth of large rivers, where not only is there the river current to deal with, but

usually a rapid tide as well and a current speed of 4 m.p.h. is not uncommon.

Regarding turning at the ends, it will be necessary when running the mile against the tide to carry on for a good distance past the last post before attempting to turn, otherwise the ship will be carried back on to the mile before she has got properly straightened up on the course. At the other end, however, the turn should be made at once, as the current will carry the ship further from the mile all the time. The actual time of starting each mile should be carefully noted, as the speed plotted on a time basis show very clearly the effect of the varying current.

The effect of the current on the speed is very important, and should be carefully studied in order that the true speed may be arrived at as nearly as possible. For instance, consider a vessel to be making one double run, that is one run with the tide and one run against. Suppose that she sets off from the landward end of the mile just after high water when the ebb tide will be gaining strength all the time. The first run will be with the tide, but by the time the vessel has turned round and got back on the course the speed of the tide will have sensibly increased, and therefore the ship will have to run against a stronger tide than she had in her favour on the first mile, and therefore a low mean speed will be shown. If, however, the trial had been delayed until nearer low water, or if the trial had started from the seaward end of the mile, then the opposite effect would have been observed. The following table shows the effects of the different conditions :—

TRIAL BEGUN FROM

	SEA END.	LAND END.
Increasing ebb Slacking flood	High speed	Low speed
Slacking ebb Increasing flood	Low speed	High speed

It must be obvious that unless very great care is taken in observing the behaviour of the tides, although six runs are made, a very false speed may be recorded. In making a series of runs it sometimes happens that the tide changes during the trial. It may then happen that a vessel may run down with the last of the ebb and then come up again with the first of the flood, and if a high speed is required instead of accurate results it is very easy to adjust the times to suit the tides. If the results are plotted on a time basis the effect of any such adjustment can always be detected at once, but after all is said and done, it is practically impossible to get a true mean speed on a river with a strong current, especially with vessels of very low speeds.

Considering the procedure in the engine room, the first step is to arrange suitable communication between the man who is taking the time and the engine room, so that the engineers may know when the vessel enters and leaves the mile. In many river steamers the engineers can see for themselves, but it is always advisable to carry out the recognised signal. If at all possible, the engine telegraph should not be used for this signalling, but should be reserved for the purpose for which it is fitted, as it sometimes happens that in an emergency the telegraph must be rung to "stop" or "full astern," and if it has been ringing promiscuously all day for other reasons the engineer may excusably fail to pick up the correct signal. It is much better to fit up a temporary electric bell circuit from bridge to engine room, and the timekeeper on the bridge may hold the push in his hand with his watch. It is possible to make a special push which will hold the stop watch as well. Under these circumstances the telegraph need not be touched from beginning to end of the trial, but if in case of emergency need should arisethe engineers will respond at once and stand by for trouble.

The next engine room point of importance is the running of the machinery, and on this, to a very large extent, depends the whole result of the trials. Many engineers who run trials have it firmly fixed in their minds that a measured mile trial should be run with all the valve gears fully linked out and the throttle valve and stop valves full open, no matter what the steam pressure is at the end. Then they close everything up and the ship crawls about until the steam rises again. Nothing could be more unlike the proper procedure.

As soon as the ship has left the wharf and has got out into the fairway, and, excepting accidents, no further manœuvres will be required by the main engines, the engineers should be informed and they should immediately proceed to open out the main engines very slowly, adjusting circulating and feed pumps as necessary, watching steam pressure and vacuum, feed temperatures, etc., until the engines are brought up to full speed shortly before the measured mile course is reached.

The boilers also should be attended to, water levels equalised and marked, so that a steady level may be maintained, and the trial finished with the same amount of water in the boilers as there was at the beginning. The water level should not be too high or priming will result, and should not be too low or cold water may have to be pumped in before the end of the trial. Every effort should be made to prevent loss of water from hot well overflow or other leakages from engine room, as it is necessary to replace this with cold water. This should be done very slowly to avoid loss of steam pressure or sudden change in the boiler circulation.

The furnaces also should be attended to before starting on the mile, all clinker and ashes removed and a good even fire obtained. Firing should be little and often to maintain conditions as steady as possible, but, at the same time, the furnace door should be open as little as possible. Tubes and back ends should be clean, and all dirt removed from stokehold.

The speed should then be maintained until word is given that all runs have been made and that the trial is complete, when the engines should be slowed down, the furnace dampers closed, boiler pressure allowed to fall and water level pumped up.

When running trials with a non-condensing engine, which exhausts into the funnel, it should be remembered that the boiler is designed to generate sufficient steam with a very brisk draught in the furnace, and if the engine is running slowly the draught will probably not be sufficient and therefore the steam pressure will fall. It will always be found, however, with an exhaust blast in the funnel that the faster the engine runs the more steam is generated, and only by running nearly full speed can the steam pressure be maintained. It will, therefore, be necessary to run the engine well up to the speed some time before the vessel enters the first mile to make sure that the steam is up to the working pressure. On no account should any vessel be taken on to the mile until the engine room has given "all ready."

During the run from the yard to the mile the indicator gear must be adjusted. This is usually done under difficulties as the strings are fitted the day before the trial, when the engines are stopped and cannot be turned, while on the day of the trial the engines cannot be stopped and the final adjustment of strings is sometimes rather difficult. Every effort should, however, be made to ensure the transmission of a proper motion to the indicator drum, as without that the resulting diagrams will be of little value.

Feed water, circulating discharge and sea temperatures should always be taken, also, of course, the steam pressure and vacuum gauges. It is very unusual to find a pressure gauge fitted on the H.P. receiver, and if a temporary one can be conveniently fixed here for the trial it should be done. It shows at a glance what steam pressure is actually being used in the engine and checks the initial pressure on the H.P. card. It also shows what pressure drop is taking place between the boiler and engine, due to boiler stop valves, tee pieces, pipes and throttle valve. All gauges should be tested before being fitted on board, and also, if possible, by a test gauge in position after steam has been raised.

For the purpose of counting the revolutions of the main engines, a counter should always be fitted, and as long an interval as possible be used. To count the revolutions of the engine for one minute may seem to be quite easy, but far more accurate results will be obtained by timing the engines by the stop watch over, say, 500 revolutions, and making the necessary calculation,

even if this method involves a little trouble. This is especially necessary in the case of very high speed screw engines.

If possible feed water and fuel should be measured. This is specially important abroad because it is very seldom done and very little accurate or reliable information is obtainable by the builders in this country, with the result that boilers are sometimes made too small, which makes a ship an anxiety to all concerned all the days of its existence.

It is now possible to get accurate meters for steam and feed, so that it is no longer necessary to make temporary complicated arrangements of tanks and piping, and if a properly made coal-measuring ring is obtained there is no great difficulty in measuring the coal either. The information obtainable makes it worth while to endeavour always to measure fuel and water. With a steam meter fitted in the steam pipe it is possible to see at once the effect of any change in linking up or other working conditions, and this instrument might easily be left in place for a short time for the benefit of the chief engineer.

Chapter 17.

LIGHTSHIPS.

During a period of about seven years a large quantity of data relating to the behaviour of Irish Lightships on their stations, under all conditions of sea and weather, was collected and embodied in a paper given at the Fifty-third session of the Institution of Naval Architects, by George Idle, Esq. The information obtained included rolling and pitching amplitudes (taken by means of mercurial clinometers), periods of oscillation and of waves, the force and direction of wind, the character and direction of waves, the positions of ships with regard to waves, etc.

The analysis of these records revealed some interesting facts and phenomena. For instance, it was found that :—

1. The greatest rolling amplitudes are attained by the old ships, of the wooden or composite class, having the double bilge logs, and which have, generally, small initial stability, and a low metacentre. In other words, the G.M. does not by itself give any indication of the ship's probable behaviour in a heavy sea.

2. Large amplitudes are reached when the sea is "breaking" (therefore steep), or, as it is termed, "confused," and when the waves are advancing on the bows or quarters. Maximum amplitudes have, in fact, been recorded when the ship has been nearly "head to" the advancing wave.

The differences between the amplitudes obtained under the above mentioned circumstances and those that are attained when the ship is riding exactly "beam to" a heavy swell, is very marked, averaging 16° to 20° for the single oscillation in favour of the "beam to" position. This suggests that there are causes productive of heavy rolling other than mere assonance between the ship and the wave.

3. The greatest angle of heel in a bad sea is always to the "lee side," that is, "away" from the advancing wave, no matter what the direction and force of the wind may be.

4. Where the bilge keels are efficient, the ship's normal period of oscillation is increased by 1 up to 3 seconds and sometimes more. When the ship is rolling in this increased period her amplitudes of roll are generally moderate. There is, of course, between the actual period of the ship and that of the wave a certain correspondence, but no continuous synchronism, even when the normal period of the ship and the period of the wave are identical. All that can be definitely said on this point is that there is apparently an attempt on the part of the wave to bring the ship to its own period. Here is seen the chief function of the bilge keel. It prevents assonance between the ship and the wave. Indeed, it may be safely asserted that without bilge keels, inefficient as they may be in some cases, these small vessels could hardly live in the seas they are sometimes exposed to.

The foregoing statements refer particularly to MAXIMUM amplitudes of roll, which are the chief concern as affecting the maintenance of the lighting and timing apparatus in perfect order and regularity.

Following these preliminary and practical investigations a series of model experiments were carried out, the model of an actual ship built for the Commissioners of the Irish Lights being selected.

The principal dimensions and particulars of the ship are as follows :—

Length between perpendiculars on waterline	100′ 0″
Beam moulded	24′ 0″
Depth from top of floors to top of beam	12′ $3\frac{1}{2}$″
Mean draught of water	9′ $4\frac{1}{2}$″
Displacement	332 tons
G.M.	2.37 ft.
Bilge keels V shaped	2′ 9″ deep

For details of the experiments reference should be made to the above mentioned paper.

The scantlings throughout in a lightship are much heavier than that required by any classification society for a vessel of the same size, in order that the greatest practicable strength may be obtained, as well as sufficient material to bear the heavy corrosion

brought upon a vessel liable to extended periods of continuous duty in exposed waters. Iron is undoubtedly superior to steel in resisting corrosion and the shell of such vessels up to the sheerstrake is generally of iron plates.

Lightships have a good sheer, giving a useful reserve of buoyancy at the ends and rendering the vessel less likely to ship water in bad weather. The Body Plan of a lightship is given in Fig. 171.

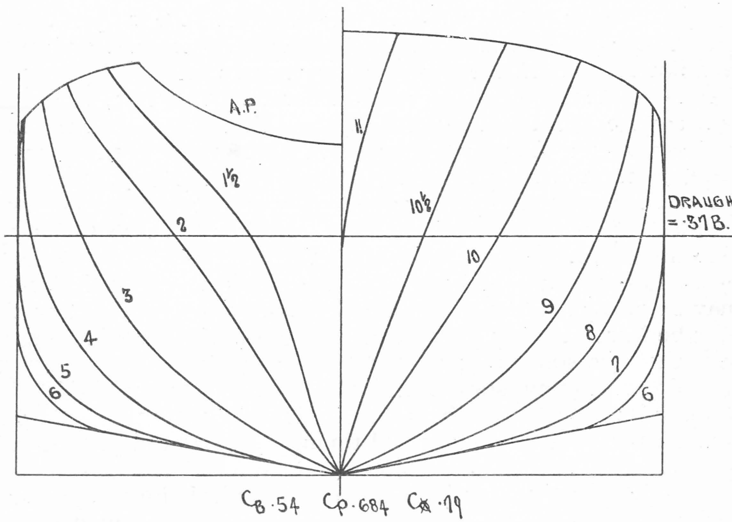

FIG. 171. BODY PLAN OF LIGHTSHIP.

The following gives the leading particulars of a lightship for service at the mouth of the Elbe :—

Length overall	172′ 10″
Length B.P.	147′ 6″
Breadth mld.	25′ 3″
Depth mld.	17′ 4″
Draught full	13′ 1″
Draught mld.	12′ 5½″
Displacement	705 tons
Block coefficient	.532
Mid. Area	.75
Waterplane Area	.80
Rise of floor	5′ 7″
G.M. fully equipped	2′ 1″
Natural period of oscillation for a double roll	11 seconds

The vessel is equipped with all the appliances which modern science has provided for the guidance of vessels when approaching land. The most important feature of the vessel, the powerful light, is installed 52 ft. above the waterline on a tower mast situated at the centre of the ship. The light is maintained by an accumulator battery of large capacity and not directly from the electric generating plant on board, in order that no fluctuations of power may disturb its intensity. A powerful siren, worked by compressed air, is provided for use in fog or bad weather when the visibility of the light is interfered with. A submarine-signalling apparatus is fitted as also an installation of wireless telegraphy.

In order to make the ship independent of outside assistance, and also to relieve the strain upon the moorings in stormy weather, propelling machinery is provided consisting of a directly reversible four-cylinder Sulzer-Diesel motor of 220 B.H.P. which when running at 280 R.P.M., is capable of giving the vessel a speed of 9 knots. The electricity for lighting the ship, charging the accumulators, etc., is supplied by a Diesel-engine-driven dynamo giving 35 B.H.P. at 450 R.P.M. A similar unit is provided as a reserve.

As the vessel is stationed in a strong tideway, special attention has been paid to the mooring arrangements. Two mushroom anchors, each of 2 tons weight, have been placed a considerable distance apart in the direction of the tides, and are connected by a cable to which in turn the actual mooring cable of $2\frac{1}{4}$ in. diameter is shackled.

Living accommodation is provided on board for 16 men.

The principal dimensions of a lightship built by Messrs. Cran & Somerville, Ltd., Leith, for the Commissioners of Irish lights, are as follows :—

Length on waterline	102′ 0″
Breadth mld.	24′ 3″
Depth	13′ 4″
Draught	9′ 9″
Height of bulwark	3′ 11″

The profile and deck plans of the vessel are shown in Figs. 172 and 173.

The main light apparatus is fitted on top of a steel mast amidships, 40 ft. above the waterline, and the day mark, a single ball is fixed near the top of a type of tall mizzen mast aft. This mizzen mast is 90 ft. long. A derrick is fitted to this mast and is worked in conjunction with a 5-ton hand winch, and is used for the purpose of bringing stores on board. With a view to providing a wireless installation later, another mast is fitted at the bow for carrying the aerials, etc., from the mizzen mast.

The hull scantlings, in view of the vessel's service, are exceptionally heavy. The midship section of the vessel with scantlings is shown in Fig 174.

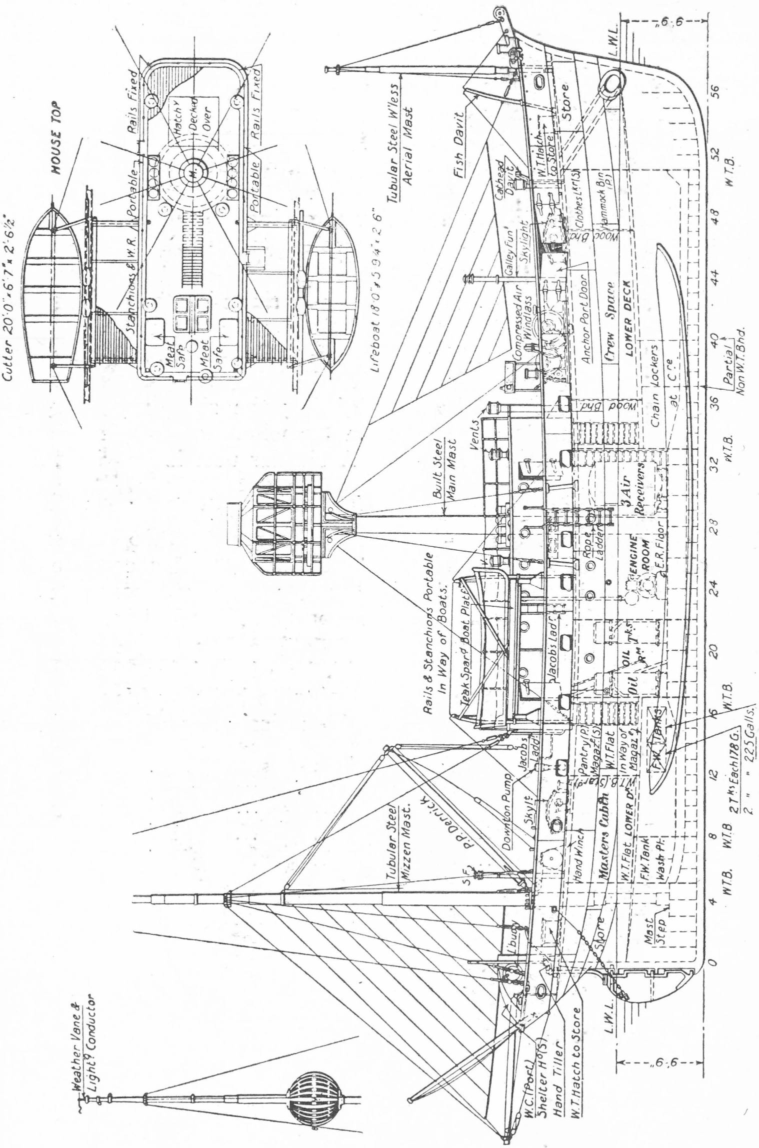

FIG. 172. GENERAL ARRANGEMENT OF LIGHTSHIP.

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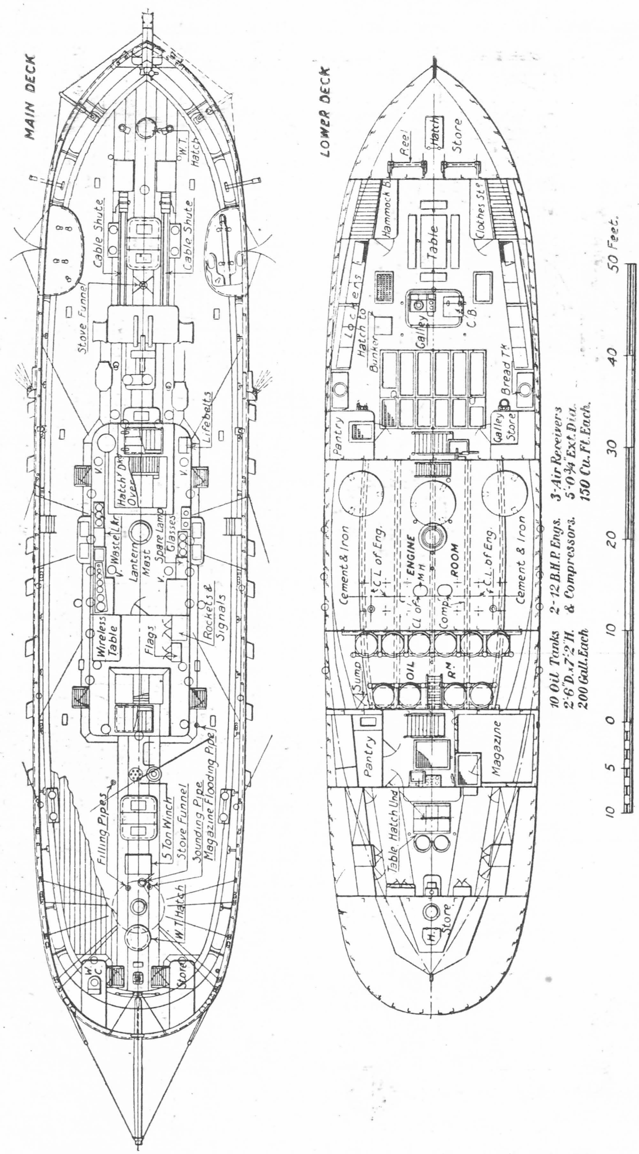

Fig. 173. General Arrangement of Lightship.

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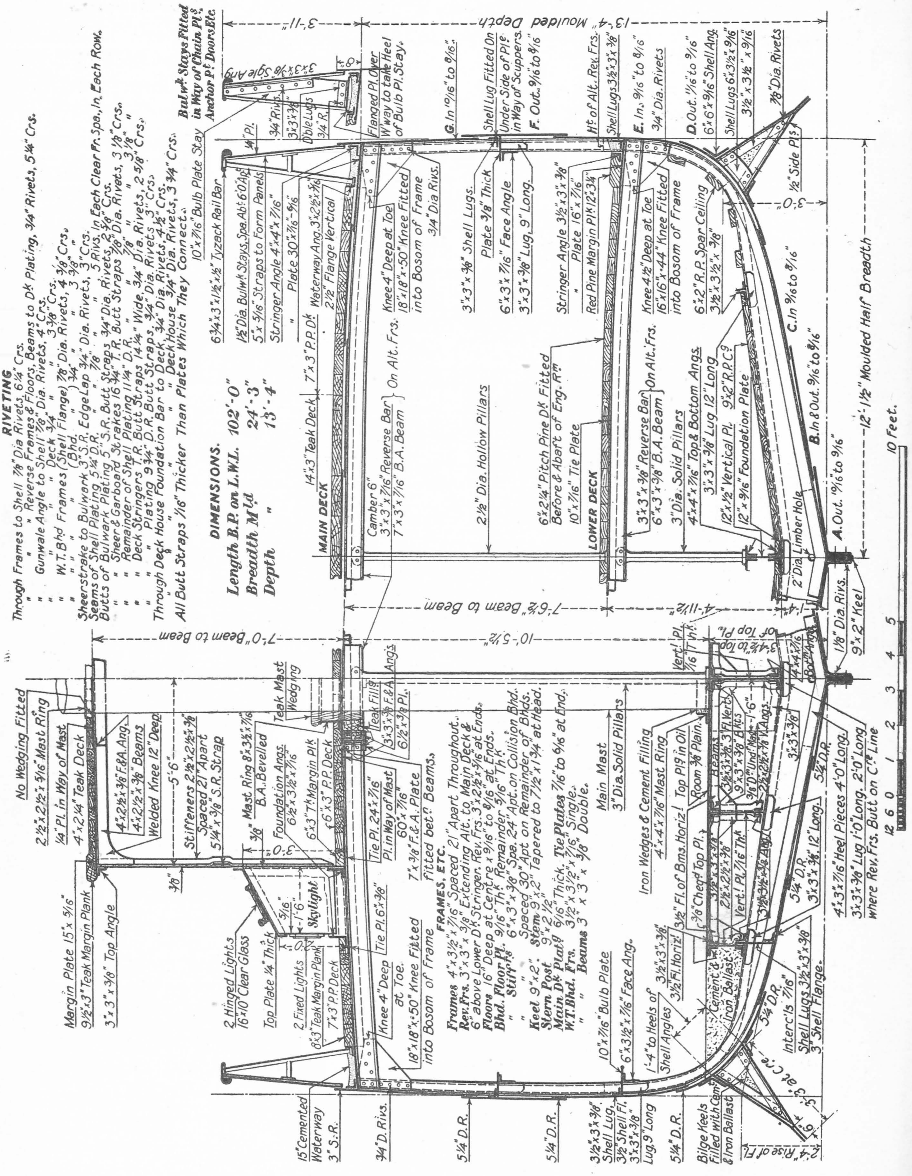

FIG. 174. MIDSHIP SECTION OF LIGHTSHIP.

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Watertight bulkheads divide the hull into six compartments. These contain stores and accommodation as follows :—

The first forward is used as a store for deck gear, and the next compartment, which is the largest, is used as crew's quarters, and is lined with teak; it is fitted out with a pantry, store, galley range, bread tanks, seat lockers, hammock lockers, clothes lockers, etc. Aft of the crew's quarters is the engine room, where there are installed two Robey semi-Diesel oil engines, each $13\frac{1}{2}$ b.h.p., two air compressors, three large air receivers which supply air at 80 lb. pressure to a large specially designed windlass on forward deck, also to the siren fog-signalling equipment. The fourth compartment is the oil room and contains 10 cylindrical tanks capable of taking 10 tons of oil and equipped with automatic gear for supplying oil to the lamp in the lantern. The fifth compartment, which is aft, contains the captain's and officers' quarters. This cabin is comfortably fitted out, all fittings and panelling being of polished mahogany. The sixth and last compartment aft is fitted out as a store for ropes, paint, etc. Fresh water tanks are placed underneath the master's accommodation, and there are two chain lockers and a coal bunker, arranged below the crew's quarters forward.

A large steel deck house amidships embraces all companion ways, and also contains workshop, lamp-trimming room, and separate lockers for flags, rockets, waste, etc. The design of deckhouse is such that no member of the crew requires to expose himself to the weather when stormy, as access is obtainable to any part from the interior of this house.

The heavy chains for mooring are handled by a large windlass, already mentioned, controlled by the compressed air plant. The hawse pipes are of special design projecting 16 in. from the bow and are enclosed in steel tubes. On the deck there are forward two steel anchor platforms fitted with gangway doors.

Two boats are fitted on davits, each side amidships, the hoisting and lowering of these being effected by Colgraves winches fitted to the davits.

The bilge keels are of special design, 3 ft. 3 ins. deep and filled with cement, and they are designed to have a powerful deterrent effect on the ship's oscillation. The weights on board are distributed in such a way as to give a maximum radius of gyration without reducing the initial stability; clinometers are fitted for the purpose of recording the oscillations and period of roll.

Chapter 18.

MARINE OIL ENGINES AS COMPARED WITH STEAM.

During the latter part of the last century, internal combustion engines were practically unknown, and even at the beginning of the present century they were regarded with a considerable amount of suspicion, many indifferent prophecies being made in reference to their future destination. The early motors, more or less following closely the newly invented motors for cars, ashore, gave sufficient indication that the engine was suitable for something more than the early high-speed launches which were installed with experimental petrol-electric engines. From 1902 rapid progress was made with this type of engine, and simultaneously Diesel and Semi-Diesel engines, which were also in the experimental stage, were quickly proving their reliability for marine work. It is unnecessary to detail the various experiments, etc., that quickly followed the advent of the internal combustion engine, since sufficient is recorded in the various annals of Marine Engineering, and all that is necessary, is to state that the engines now made and installed in vessels, are equally reliable as, and hold several advantages over, the steam sets. The advantages as far as the owners of vessels are concerned are :—

1. That no boilers are required, and, therefore, there is less weight of machinery, and greater space available for cargo, etc.
2. That the engines are lighter, and occupy less space, again increasing the cargo space, or alternatively, the same deadweight can be carried on less dimensions of hull, thus reducing first cost and reducing running costs.
3. That, with small vessels, the fuel can be carried in the engine room, or on the deck, thus the space otherwise occupied by the bunkers is again on the deadweight carrying capacity.
4. That the engineering staff is considerably reduced, firemen and trimmers not being needed, thus the working expenses are reduced.
5. That there are no stand-by losses, which is an important consideration with certain types of vessels.

As far as the Engineers are concerned, the advantages of internal combustion engines are :—

1. They may be started almost instantly.
2. They are easy to operate.
3. They are very much cleaner to work with.

The disadvantages, as far as the Engineers are concerned, are as follows :—

1. That compressed air is necessary for reverse, as danger may result should the supply be exhausted. (Note.—

Some large vessels are fitted with a separate air compressing set. There are one or two direct reversible engines on the market).

3. That there is a loss of power when a clutch has to be interposed between the engine and the propeller.
4. That when a reverse gear is fitted, there is a loss of power, and with reduction, a very low speed astern.
5. There is considerable danger when fuel of low flash point is used; the efficient ventilation of tanks, etc., is important.
6. That trouble is experienced by rapid carbonisation of sparking plugs, valves, etc., and trouble with ignition gear. This is experienced with the petrol-paraffin engine, but with care and frequent cleaning little trouble will be encountered.
7. That the exhaust gases cannot be used expansively as with steam, a separate charge being necessary for each cylinder, thus there is a loss.
8. That the heads of the cylinders become excessively hot and require to be water cooled, thus reducing the efficiency of the engine.
9. That this type of engine is single acting, *i.e*, receives its impulse on one side of the piston only, thus to obtain the same power on the shaft two cylinders become necessary.
10. That the speed of the engine is very high, and the engine is liable to race when running free, or when the vessel is in a rough sea, and the propeller leaves the water.
11. That the speed of the engine when running light causes excessive vibration.
12. That the exhaust gases cannot be condensed to reduce the back pressure off the piston. The exhaust varies with a pressure of 15 to 20 lbs. per square inch, absolute, and the steam engine only gives a pressure of 2 to 3 lbs. per square inch, absolute.

The disadvantages enumerated above are not serious, although many have urged them, perhaps to an excess. They can more or less be overcome, and the advantages the engine holds have been sufficient to warrant a growing industry.

As far as the Naval Architect is concerned, the points which need his special consideration are:—

1. That the bed plate of the oil engines (excluding many of the very large Diesel engines) are much lighter than the bed plate of steam engines, and owing to the higher speed and the incessant intermittence of the impulse a specially designed seating arrangement must be provided.
2. That owing to the lighter weight of the engine, the shaft must be fitted lower to allow the propeller being sufficiently submerged when the vessel is light.

3. That owing to the greater speed of the propeller, the after lines of the boat should be suitably modified in order that the greatest efficiency may be obtained.
4. That owing to the higher speed of the engines, a propeller of special design is needed.
5. That the engine room should be as airy and light as possible, with an efficient ventilation system, in order that gases, etc., may freely escape to the atmosphere.
6. That an efficient pumping arrangement be fitted in order to free the bilges of oil, etc. Drip trays should, in small vessels, be fitted under the engines and fuel tanks.

A point which is of interest to the Owners, Engineers, and Naval Architect, is that auxiliary power cannot be drawn from the main engines. An air compressing plant has been fitted to the latest type of Bolinder engine which, being self-contained, does not require a separate plant, and most of the engines have a small bilge and circulating pump running off eccentrics on the main shaft, but any further auxiliary machinery needs a separate plant. Thus winches must be directly coupled with a motor, unless a bevel gear arrangement is fitted from the main engines—a method which is entirely unsatisfactory—or by fitting a donkey boiler and the usual steam winches—a method which destroys the idea of a motor ship. If a large bilge pumping arrangement is needed, a separate motor must be fitted.

However, returning to the list of advantages and disadvantages, a few figures, etc., will show in a concrete form the results obtained from various motor vessels.

In Chapter 11 particulars are given of the saving in deadweight, etc., by fitting a Kromhout engine in a coasting vessel instead of steam, and below are given further particulars of a somewhat smaller vessel.

STEAM SET.

Weight of steam machinery	100 tons
Weight of coal bunkers	60 ,,
Feed water	10 ,,
Stores (say)	5 ,,
	175 tons

OIL SET.

Weight of engines, including auxiliaries	45 tons
Oil fuel, for same radius as above	15 ,,
Donkey boiler, inclusive	10 ,,
Stores (say)	5 ,,
	75 tons

By the above it will be seen that a clear saving of 100 tons is made on the cargo carrying capacity, which equals roughly about 4,200 cubic feet of space. This is very considerable, for with a vessel of 800 tons, there is a saving of $12\frac{1}{2}$ per cent. If instead of the donkey boiler, etc., motor winches had been installed, the saving would have been increased by about 8 tons, inclusive, thus making a total gain of 108 tons. This is with a coasting vessel, and turning to barges and lighters we find that the saving of space is again comparatively great.

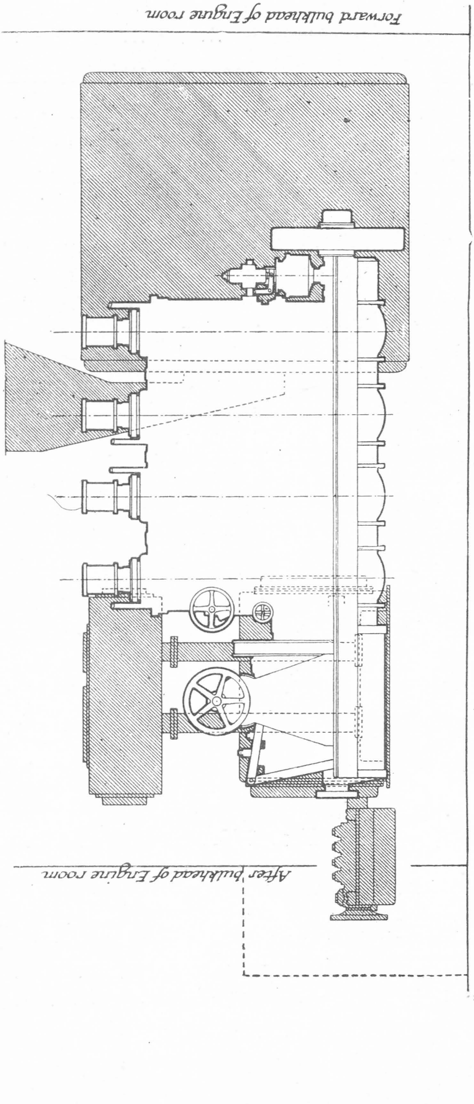

FIG. 175.

STEAM BARGE.

Cargo	250	tons
Engines and Boilers	25	,,
Bunkers	20	,,
Feed water and stores	7	,,
	52	tons

MOTOR BARGE.

Cargo	250	tons
Engines and auxiliaries	10	,,
Oil fuel, same radius as above ...	5	,,
Stores	2	,,
	17	tons

With the above a saving of 35 tons is made in a vessel of the same deadweight carrying capacity, thus the dimensions of the hull for the oil vessel are less than that of the steam, or if the same dimensions are kept, the carrying capacity of the motor barge would be 285 tons, that is, an increase of about 1,450 cubic feet.

Fig. 175 shows a Kromhout engine of 435 I.H.P. standing against a 350 I.H.P. steam engine. A further comparison is shown in Fig. 176, which is a steam trawler, the lighter and smaller oil engine being shaded. Here the gain can be clearly seen, and no comments are necessary.

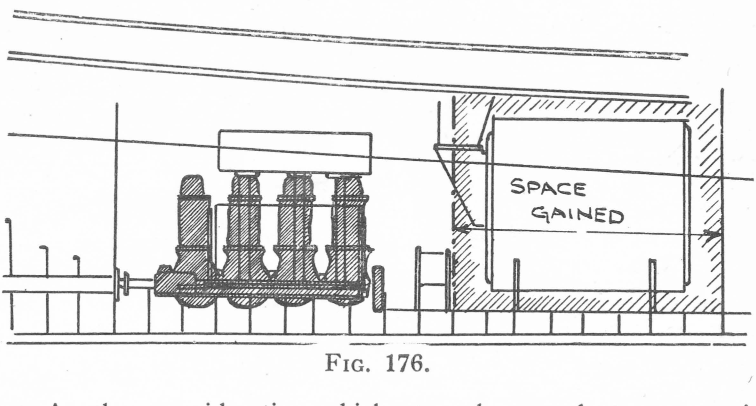

FIG. 176.

Another consideration which strongly appeals to owners is that the weight of the fuel, and the space which it occupies is, for the same radius, much less than that required for steam. With the foregoing cases, it will be seen that the saving in one case is 45 tons, and in the other 15 tons. This shows that the saving

is approximately about 75 per cent. The tanks may be fitted in such places as the after peak, and in the engine room, whereas with coal special bunkers have to be allotted.

A comparison of the fuel consumption for a 3,500 B.H.P. Deisel Engine, and a 3,000 I.H.P. Triple Expansion Riciprocatory Engine is given below.

STEAM SET.

Main and auxiliary machinery fuel consumption (coal) at 1.7 lbs. per H.P. per hour	55	tons per day

MOTOR SET.

Main engines, fuel consumption (oil) at 0.45 lbs. per H.P. per hour	17.0	,, ,,
Auxiliary machinery, fuel consumption at 0.07 lbs. per H.P. per hour ...	2.6	,, ,,
	19.6	,, ,,

The fuel consumption varies, of course, with the different makes of engines, but over a large number of trials carried out on the test benches, of different makes of engines, the fuel consumption at full load varied between 0.425 and 0.548 lbs. of fuel oil per B.H.P., per hour. The average mechanical efficiency and brake thermal efficiency of these engines were given as 78 and 28 per cent. respectively. There is a rapid decrease in the fuel consumption per B.H.P. per hour, as full load is approached, thus a 300 B.H.P. when running at quarter load consumes 0.635 lbs. of fuel per B.H.P. per hour. At full load the consumption falls to 0.42, and at 30 per cent. overload it is 0.41 lbs. of fuel per B.H.P. per hour. These figures are very instructive, and may prove of use to owners anticipating the installation of these types of engines in their vessels.

A smaller engine room complement again reduces the running costs, and with oil engines, the usual stokers and trimmers are not needed. Taking an example from a large craft, they may be tabulated as follows :—

STEAM SET.

Engineers	4
Donkey Men	2
Greasers	6
Stokers	16
Trimmers	4
	32

MOTOR SET.

Engineers	6
Greasers	6
	12

When taking an average wage of £3 0s. 0d. per week, the wages for the engine room staff for the two boats would be £96 0s. 0d. and £36 0s. 0d., a clear saving of £60 0s. 0d., or $66\frac{2}{3}$ per cent. being effected. In small vessels carrying low powered engines, say 80 to 200 B.H.P., only two or three engineers are carried who do their own greasing, but with a steam vessel of equivalent size at least three engineers and four firemen and trimmers are needed, so that even here a saving of over 50 per cent. is effected.

It is on points such as these that the oil engine particularly finds favour with owners, since where the working expenses can be reduced to a minimum, and the cargo carrying capacity increased to a maximum, the greatest profit is made and the greatest return for the capital is given.

Reverting to the second list given at the beginning of this chapter, the instantaneous starting is of great importance with marine work. Boilers have to be lighted some hours before the time of sailing, and there is a considerable waste of coal, at least as far as the owners are concerned. Petrol-paraffin engines can be started instantly, but the Semi-Diesel engines need about half an hour to heat the bulbs by the blow lamp. The Kromhout engine of the "M.P." type is an exception, however, for with an improved type of blow lamp, a start can be made within four minutes, or with the patent electric starter, can be started immediately from the cold.

The operation of practically all makes of oil engines is simple, and although they may be preferable, skilled drivers are unnecessary. As an instance, mention may be made of several vessels employed upon the fishing trade which have been fitted with oil engines, where the Skipper and Mate conjointly perform the duties of Engineer, and it may be expected that very little attention can be given to the engine when coming into or leaving port, as well as on the fishing grounds. The engine controls are led to the deck, and after starting the engine will be left, perhaps for a few hours, without any attention whatsoever. These men as a rule have little mechanical experience, yet cases of serious breakdowns are rarely met with.

That the engines are very clean to work with cannot be denied. With automatic lubricating contrivances, only just sufficient oil is given to the various moving parts (this method has an economical advantage), and the cranks are housed which prevents oil from being thrown around the engine room. A greater advantage is that of taking in fuel. With steam engines, the dirty and laborious job of coaling takes some hours to perform, besides having the great disadvantage of spoiling highly regarded paintwork. On the other hand, with oil sets, fuel can be taken in very quickly, and being pumped directly into the tanks, causes no mess on deck or below.

Several arguments are urged against oil engines on account of reversing, etc., but practice has proved that under normal circumstances, compressed air starting and reversing, and the fitting of clutches, leave nothing to be desired. The compressed air or direct reverse, if the latter be regulated, to a nicety, is preferable to the reverse gear contained within the clutch. With regard to the mechanical efficiency of oil engines, on several tests on various engines, the mean mechanical efficiency was found to be 74 per cent., which compares very favourably with the efficiency of steam sets. The thermal efficiency of the fuel is a considerable help to oil engines, values of which are given as follows :—

Thermal Efficiency.		Type of Engine.
12 per cent.	...	Reciprocating steam engine and boiler.
23 ,,	...	Petrol engine.
29 ,,	...	Semi-Diesel engine.
37 ,,	...	Diesel engine.

Much has been said and written about the inability of oil engines to keep running for considerable periods, such as is needed with vessels making long voyages, but the achievements of several vessels are sufficient evidence to the contrary. With most of the engines now on the market, there is nothing left to be desired as regards to the stability of design and the reliability of construction of the various parts. That the whole engine is substantially and strongly built is shown by the small number of serious breakdowns, and the list given below should be of sufficient evidence to show that even the most delicate parts are sufficiently strong to withstand all normal working. The list gives the percentage failings of various parts of the machinery and has been compiled from cases which have come under the notice of various insurance companies.

Analysis of Failures of Parts of Semi-Diesel Engines.

Part which was believed to have given way first.	1910. Per cent.	1922. Per cent.
Pistons	16.4	15.4
Connecting rods and bolts	10.9	22.0
Cylinders and cylinder heads ...	25.0	20.0
Main shafts	17.5	18.3
Silencers, etc.	1.4	2,4
Clutches and gear	1.3	2.6
Governors and gear	2.6	3.5
Crank housings	2.1	3.5
Holding down bolts	8.2	5.4
Air valves	7.3	4.2
Total wrecks, cause not ascertained	7.3	2.7

Analysis of Failures of Parts of Petrol, Paraffin Engines.

Part which was believed to have given way first.	1910. Per cent.	1922. Per cent.
Valves and valve gear	42.7	44.0
Pistons	5.2	4.8
Connecting rods and bolts	9.5	8.5
Cylinders and cylinder heads ...	8.8	8.7
Main shafts	8.0	9.0
Silencers	2.8	3.2
Clutches and gear	1.3	1.4
Governors and gear	3.2	2.8
Crank housings	2.8	2.6
Holding down bolts	2.7	2.7
Miscellaneous	4.0	4.0
Total wrecks, cause not ascertained	9.0	8.3

In Clause 10 in the third list given at the beginning of this chapter, note is made of the high speed of the oil engines and their liability to racing when running light, As most of the engines now made are fitted with governors, which are reliable and sensitive, the running of the engines both when light and in a sea way, is practically constant. The "hit and miss" type of governor, which is regulated by the tension of a spring on the fuel pump plunger, is a common type, although more constant results have been obtained with the centrifugal governor controlled by weights coupled to a wedge which reduces the stroke of the pump plunger, and thus reduces the explosive charge.

Although the first installations were marked with excessive vibration, the fault was more of the Naval Architects than the engines, owing to the improperly designed engine bed, but with experience which has followed, this disturbing factor has been minimised. Fig. 177 shows an engine seating for a steel vessel, and Fig. 178 shows an advisable arrangement for a wood boat. It will be noticed that with each the longitudinal bearers are continued a considerable distance forward and aft of the engine, so that the weight, etc., of the engine may be distributed over as large an area as possible; in many cases it is possible to scarph the longitudinal bearers with the keelsons, and wherever possible this method should be adopted. Many makes of engines do not allow the bearers being continued forward owing to the diameter of the flywheel, which exceeds the distance between the holding down bolts, and it would be advisable for oil engine designers to see, in future, that the necessary inertia for the flywheel is accommodated within as small a flywheel diameter as practicable. Both with steel and wood, the bearers are supported, and prevented from tripping, by fitting deep floor plates and struts which are continued as far round the bilge as possible; with wood the

floors should be sufficiently long to take at least one through fastening with the bilge stringer. Both the longitudinal and transverse supports are well connected to the shell either by substantial angles or through bolts.

The last objection raised is that of the back pressure upon the piston, but with an efficient and well designed silencer, shock, etc., can be reduced to a minimum. A gradual fall of pressure to that of the atmosphere, and the fitting of baffle plates, will leave a clear run to the atmosphere, and noise will not be an inconvenience. Secondary silencers are often fitted, especially in funnels, thus giving an appearance to which we are more accustomed, materially assist in the reduction of noise; it must be remembered, however, that the efficiency of the engine is reduced when silencers of excessive volume are fitted.

Before passing on to the necessary modifications in the design of the hull and propellers of motor vessels, a few words may be said on the arrangement of the engine room. When a comparatively small radius of sailing is required, the fuel tanks may be fitted in the engine room, at each side, and strapped to the reverse frames. The tanks should be of galvanised iron or steel, they must be oil tight, and capable of withstanding a pressure corresponding to a head of water of at least fifteen feet. Diaphragm plates must be fitted, and a manhole provided to allow of cleaning. Circular tanks, with the draw off cock at the bottom, are the best shape of tank, because they reduce the chance of corrosion,

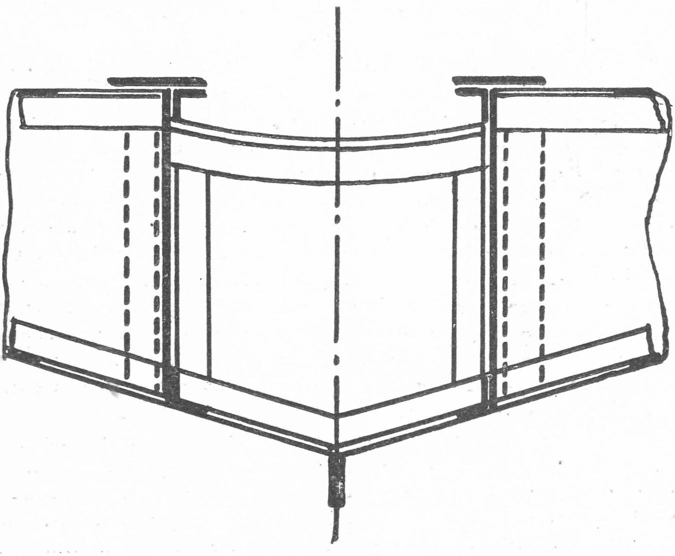

Fig. 177. Oil Engine Seating, Steel.

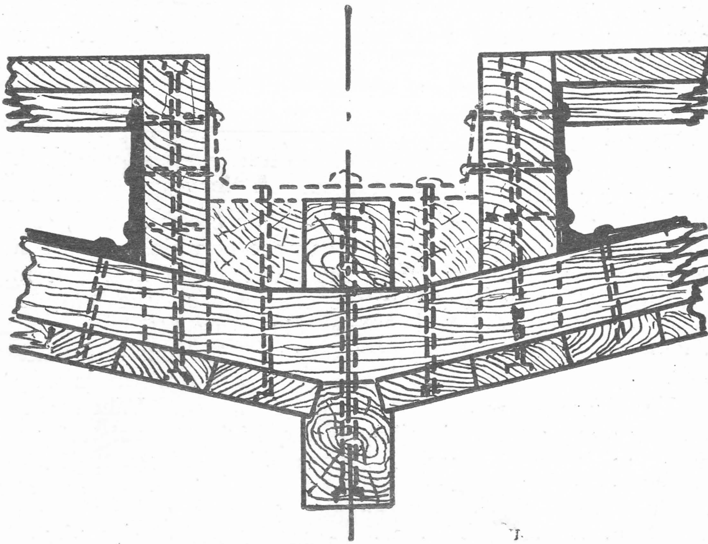

FIG. 178. OIL ENGINE SEATING, WOOD.

but these cannot always be fitted owing to their weight, and the impracticability of strapping them to the beams and frames. If the dimensions are large, the tanks should stand upon the floors, the draw off cock being as low as possible. The filling pipe is screwed to a brass deck plate, to which is fitted a brass screw-on lid; care must be taken to ensure that no water finds its way into the tanks. A levelling pipe is often fitted to tanks standing on each side of the vessel in order that an equal amount of oil is taken from each tank. A ventilator, usually a bent pipe, must be fitted at the top of all fuel and oil tanks, to emit the various gases.

A pipe is generally led from the draw off cock, when the fuel tanks are fitted on the tops of the floors, to a semi-rotary hand pump, which delivers the oil to a daily service tank. This tank, of a capacity between 10 and 50 gallons according to the size of the engines, is fitted as high as practicable in the engine room so as to give a reasonable pressure of oil at the fuel pumps. The Board of Trade, as previously mentioned, require fuel tanks fitted in a separate oil tight compartment, in passenger vessels and launches. The lubricating oil tanks are generally strapped to the frames, and pipes are often led to the automatic lubricators, so that little is left for the engineers to attend to in this direction.

The circulating pump arrangement is simple. The pump suction is led to the turn of bilge, and is fitted to a non-return valve, and in turn to a sea-cock. A rose plate should be fitted

to the aperture on the outside, to prevent the cock becoming choked. The pump discharge is led to a non-return valve fitted immediately above the water line; as a measure of safety, a sea-cock is often interposed between the non-return valve and the shell plating.

The bilge pump suction, in a larger vessel, is generally led to a suction box, from which are several pipes running to the various compartments and bilges. A delivery box is also fitted, so that the water, may be delivered overboard, or on deck, at will. The overboard discharge should be led to a non-return valve and sea-cock.

When water tanks are needed for the water drip—an item which has disappeared with several makes of engines—they are fitted against the frames at a sufficient height to give a reasonable pressure.

The exhaust pipe is sometimes water-cooled, but in any case it is desirable that it be covered with asbestos, so that nobody will be hurt or burnt should they knock against it. The lead from the silencer should be as straight as possible, and made in a sufficient number of small lengths to allow for occasional cleaning.

All pipes should be as straight as can be, and great care should be taken to prevent possible air locks. Accessibility is important, and for this reason all pipes should be so placed that they may be instantly attended to. The fuel pipes, which should be of copper, must have the necessary filters interposed between the pumps and tanks, and when the flash point of the fuel is low, gauze wire must be fitted in the pipes at suitable distances as a precaution against fire and to prevent flames and explosive gases finding their way into the tanks.

A skylight is generally fitted directly above the engine, and care should be taken to ensure that the coamings are of sufficient height to give reasonable protection to the engines in the case of the glass being broken; it must be remembered that the cylinder heads are very hot, and a deluge of water pouring over them may cause them to crack. In large vessels some provision must be made for the removal of the pistons, etc. An H bar is usually fastened to the under side of the beams, as near the centre line of the vessel as possible (sometimes two are fitted, one on each side of the skylight). This bar carries a suitable trolley, arranged so that it may be moved into any position, attached to which is a lifting gear.

An important consideration in the lay out of an engine room—and one which is often sadly neglected—is that of providing sufficient space all round the engine. The air valve, fitted to the crank housing of Semi-Diesel engines, requires frequent attention, and the bilge or the circulating pump, one of which is usually at the back, requires to be easily accessible. The fitting of the connecting rod to the crank shaft, and the inspection of the bottom ends, have frequently to be undertaken, and since only a small space is

allowed at the air valve apertures, or the crank housing inspection doors, enough room has to be arranged for at the back of the engine to allow a man to fit the bottom end bolts, etc. Light and ventilation, although not unique, are nevertheless highly important. The reasons for efficient lighting are obvious, but with ventilation it must be remembered that the engine room is often full of gases which as soon as possible should be discharged to the tanks, it is necessary, in starting, especially with Semi-Diesel engines, to make trials to ascertain whether the bulb, etc., is of sufficient heat for starting, and consequently the exhaust gases are emitted into the engine room from the compression cocks, and the importance of the speedy removal of these dangerous gases—dangerous as far as human health is concerned—is easily recognised. Four ventilators of the cowl type should, if possible, be fitted to every enclosed engine room, two on opposite sides being continued down to the floors and the others stopped at a reasonable distance below the deck, so as to ensure an efficient circulation of fresh air.

As a final word, in the installation of oil engines the greatest care should be taken against the undue waste of lubricating oil, and for this reason, and also for that of preventing oil from entering the bilges and rendering the pumps inefficient, etc., drip trays should be fitted under the engines wherever possible. The oil thus collected, most of which has been drained off from the crank housing, can, after being filtered, be re-used, even if not for engine lubrication, for some other work. Drip trays should also be fitted under fuel tanks, filters and in any other place where there is a likelihood of the oil escaping.

The design of the motor ship varies from that of the steamer insomuch that precautions must be taken to ensure the greatest efficiency possible from the fast running propeller. If the after lines of a motor vessel do not allow a good, clear run of water to the propeller, the latter will become "choked," *i.e.*, instead of thrusting a stream of water aft, and thus driving the vessel forward, it will simply churn a collar of water round with it, making plenty of wash, but not driving the vessel forward. The after waterlines, therefore, should be sufficiently fine to allow a good body of water entering into the root of the propeller. Since the motor is placed as low as practicable in the vessel, it is apparent that the lower part of the after sections will be fine, and in some ways this is an advantage, for the sections can be "filled-out" towards the deck and thus preserve the buoyancy. On the other hand, the area of the bottom, aft, is reduced, and if the vessel frequently takes the ground some form of stiffening must be made so that no damage will result. The propeller being low, prevents a large sweep-up of the lower part of the stern frame, and since motor vessels usually trim by the stern, the lower connecting piece is open to damage, and should fracture occur,

the propeller is almost sure to be broken also, since there is but little clearance allowed between the tips of the propeller and the connecting piece; often the connecting piece is made unusually strong, the cross sectional area being about $1\frac{1}{4}$ that of the body post so that fracture is less likely.

The propeller, owing to its greater speed, has a pitch-diameter ratio much less than that of a steam-driven propeller. It is, however, advisable to keep the ratio within proper limits, else the pitch angle will be reduced to an inefficient value, and various troubles such as cavitation, etc., will result. If the pitch angle is kept within practical limits, the blade area relatively to the disc area can be increased rather than the diameter, and greater propulsive efficiency will be obtained although there may be a greater apparent slip. The absorption of power can be regulated by the area of blade independently of the diameter, although greater efficiency would be obtained by propelling a small column of water astern at a relatively great velocity than by propelling a large column at a comparatively small speed. It is from the point of proportioning and disposition of the blade area that the greatest efficiency can be obtained from a fast running propeller. If the blade area is kept at about 33 per cent. of the disc area, and the projected area ratio kept within suitable limits, consistently good results should follow. The blades should not be of the leaf shape, so common with propellers driven by steam sets, but rather they should have a comparatively narrow width at the root, and a somewhat large sweep out of the driving edge, the greatest width of developed blade being about two-thirds of the diameter, thus giving a broad, flat tip which is capable of dealing with the water stream effectively.

In wooden vessels the after side of the sternpost should be well chamfered so that there may be a good flow of water to the root of the propeller, and thus reduce the eddies which prove to be a big factor in resistances. Trouble in this direction is seldom experienced with iron or steel boats, for the reason that the body post of the stern frame is of small thickness. If required, the stern post may be stiffened by fitting plates on either side and through bolting them.

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